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Semantic Model Workspace Industrial Robot

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Abstract: *This work presents a fundamental formal definition of semantic network objects. This can be used to describe dynamic systems, which can be a robot workspace model. Advantages and disadvantages of using semantic networks for describing objects of industrial robot's workspace are determined. Three types of semantic network structures are given. In work, a structural elements hierarchy of semantic network for industrial robot's workspace was created on basis which a semantic model was built for describing classification properties of objects in workspace as a dynamic object. In course of model building, types of objects, semantic features of nodes, their attributes were determined, types of links between objects were determined. This is important for the analysis of dynamic processes and their applications.*

Keywords — workspace, robot, semantic networks, models**.**

1. INTRODUCTION

Modern robotics began with industrial robots in middle of last century [1].

Today, industrial robots (IR) of completely different types are successfully used in very many industries, both for simple movement of objects and for performing complex work. Workspace exploration and analysis is not just a volumetric analysis tool, it is an opportunity to predict number of decision sets, as well as presence of boundaries within which decisions can be made within workspace.

Analysis of workspace is more necessary for moving IRs as it further helps to research, evaluate and optimize design of robots based on certain criteria with due regard for ergonomics and usability [2].

To avoid collisions in workspace of robot, you must at least know positioning of objects in this area, but it happens that workspace is a dynamic environment, that is, objects also move. When building modern intelligent systems, semantic, frame and universal forms of knowledge object model are used [3]-[5].

Search for ways to study systemic relationships of objects led to emergence of semantic networks theory. Description of workspace using semantic networks allows you to give information a hierarchical structure and in future to store and organize it.

Simplest form of semantic network is often used to display a system of concepts in a problem area and output in this system. In a number of tasks related to planning and controlling movement of IR, it is more rational to use models that describe not generalized coordinates of IR, that is, work in configuration space, but in Cartesian coordinates, that is, in workspace. Therefore, task of formalizing and visualizing IR workspace remains relevant. Thus, it is important to form a description that formalizes and details cause-effect relationships between IR and workspace objects.

2. RELATED WORK

Workspace analysis is a common research topic, numerous papers provide only estimates for specific project, and there are no generic software tools for various robot configurations.

Robotics is promising area that contributes to increasing interest in analyzing, formalizing and calculating boundaries of workspace to optimize design, and assess effectiveness of robots.

In [2] universal research-oriented environment for analyzing and visualizing workspace. It is based on Orocos Kinematics and Dynamics Library (KDL) and Matlab Robotic Toolbox. Authors [2] have identified optimal parameters for computer form (2D and 3D) and workspace size. Paper considers process of creating three-dimensional workspace based on three-dimensional reconstruction from boundary points.

Analysis of robot's double coordination workspace based on Matlab is given by authors in [6]. The work also describes in detail optimal coordinated workspace of robots. Using 3D modeling environment SolidWorks2012, interaction system model of two robots was created to study space of their interaction.

Creation and calculation of shape border and volume of working space is very important, therefore there are many works, among which we will single out [6]-[13].

Based on Monte Carlo method, workspace of double robot was solved in [6]. Extreme value theory method is used for analysis and calculation to extract exact contour of common area boundary of dual robot workspace, as well as determine boundary surface of joint space and limit position of dual robot.

In work [7], to obtain shape and size of workspace, authors also used numerical method – Monte Carlo.

General numerical evaluation for defining and evaluating workspace using workspace discretization is described in [8].

Procedure for determining functional working space of 6R robot using direct kinematics and geometric methods is described in detail in [9]. The authors describe very extensively methods for defining functional workspace (manual approach, empirical interpretation, analytical and geometric approaches, etc.).

Use of analytical methods is disclosed in [10]. This paper proposes a new method for obtaining solutions in closed space for inverse kinematic problem of redundant serial manipulators. The authors consider analytical method as closed methods that are used for non-redundant reduced manipulators. Such methods are expressed as functions in terms of "pose".

In work [11] also deals with analytical method. An analytical method for determining set of permissible poses is considered.

In [12], numerical approach to assessing manipulator working space is presented. Method is based on concept of non-uniform coverage, in which workspace is solution to system of nonlinear inequalities with Lipschitz functions.

Geometric method for calculating working area of constant orientation of six parallel PRRS manipulators is described in [13]

Also, geometric method for solving a stable workspace is described in [14]. Stable space was formed from general stability conditions, which changed depending on pose of robot and mass of captured object. The authors discuss in detail key issues of solving robot's workspace, including search for stable working conditions for robot. Based on geometric method, workspace of robot in various positions was analyzed by method of division into a grid and in combination with Matlab, VB and Solidworks programs. As result, an automated computing system for a stable workspace has been developed.

3. FORMAL DEFINITION OF SEMANTIC NETWORKS

The objects of semantic network (SN) are concepts that carry meaning (semantics), and links are relations between concepts.

SN is simple object system if objects do not implement procedure for calculating estimates, and can be represented by continuous graph with labeled vertices.

Let's give a formal definition of semantic network. Let a finite set of symbols (attributes) be given [15]:

$$A = \{A_1, ..., A_n\},$$

and many relationships:

$$R = \{R_1, ..., R_m\}.$$

An intension or scheme of some relation R_i is set of pairs [15]:

$$INT(R_i) = \{...[A_k, DOM(A_k)],...\},$$

where:

R_i – relationship name;

$DOM(A_k)$ – set of attribute values A_k for relationship R_i; $A_k \in A$, at $k = 1...n_i$ – relationship attributes R_i;

n_i – positive integer (cardinality of ratio).

Union of all domains is set of all objects on which relationships are defined. They are used to create a knowledge base of semantic kind.

An extensional relationship R_i is a set of facts (relationship factors R_i) that determine concretization of certain relationships between objects.

An extensional describes database within knowledge base of semantic form [15]:

$$EXT(R_i) = \{F_1, ..., F_p\},$$

where:

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F_k – relationship factors R_i, written in form [15]:

$$F_k = (R_i \ldots A_k \in V_{ikp} DOM(A_k) \ldots),$$

where: V_{ikp} – k-attribute value of p-factor of extensional relationship R_i.

Using SN to workspace describe will allow:

- provide visibility of knowledge system presented graphically;

- describe a rather complex subject area;

- universality, achieved by choosing an appropriate set of relations.

Disadvantages include:

- formalization, application and change of knowledge in course of displaying objects of "real level of complexity" workspace – laborious process, especially in presence of multiple relationships between its concepts.

- complexity of finding solution in semantic networks.

To build a domain model in form of semantic network, consider following algorithm [16]:

1. Initially, it is necessary to separate all concepts of subject area:

- macro concepts (class of concepts);

- meta-concepts (generalized concepts);

- microconcepts (elementary concepts).

2. Then highlight general and distinctive properties, features inherent in each level of concepts.

3. Determine connections between concepts related to same level.

4. In the end, establish inter-level links.

However, such an algorithm for structuring knowledge when developing a model for their presentation and control is rather laborious.

It is determined that different types of structures are used in semantic networks, but requirement of associativity, that is, grouping of information around facts, attributes and objects, is a common feature.

Types of SN structures can be:

1. Homogeneous and heterogeneous networks.

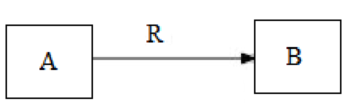
Homogeneous networks have only one type of relationship (arrows);

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 research. Heterogeneous networks can be represented as an interweaving of tree-like multilayer structures [17], [18].

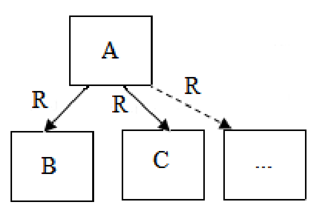
2. Networks with binary and non-binary relations [19].

There are only two concepts related to binary relations. Such relations are quite simple and convenient from point of representing view on a graph in form of an arrow between two concepts (fig. 1a).

Non-binary or N-ary (it is determined that in practice, relations are used that connect more than two objects). They are more complex because, in order to represent all relations on graph, one can get confused (fig. 1b).



a)



b)

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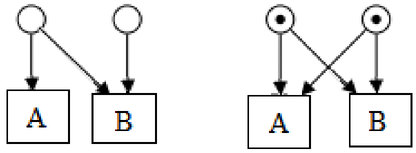
Figure 1. Networks with binary and non-binary relationships

3. Symmetric and Asymmetric (see fig. 2). In case of symmetry, precise characteristics are obtained; for asymmetry, lower and upper bounds were obtained [20].



a) b)

Figure 2: Networks with symmetric and asymmetric relationships

4. Development of Industrial Robot Workspace Model in Form of a Semantic Network

An industrial robot workspace is proposed to consider a space that includes 2 classes:

1. Working area.

The working area of an industrial robot (WIR) is space of certain area in which manipulator can perform work without violating established characteristics.

The working area is defined as volume of space, and can be from 0.01 m^3 for highly accurate robots, and up to 10 m^3 or even more (for mobile robots).

It is clear that, depending on type of production (warehouse work, assembly, welding, drilling, casting, forging, heat treatment, painting or washing, etc.), specificity of working area of robot depends.

The work area may include: machines; tools; equipment. You should also consider mobility or stationarity. Since mobile robots are capable of transporting, orienting and coordinate movements, and stationary ones only of transporting and orienting movements, stationary robots have working space limited to working area.

2. Environment.

Objects of environment include what surrounds robot or can surround it in course of its functioning: person; other robots (robocars, etc.); industrial containers (pallets (fig. 3a) [21], containers (fig. 3b) [22], bunkers (fig. 3c) [23], buckets, boxes, barrels and tanks, etc.).

a) b) c)

Figure 3. Production packaging

Let's represent structure of classification model of industrial robot workspace in fig. 4.

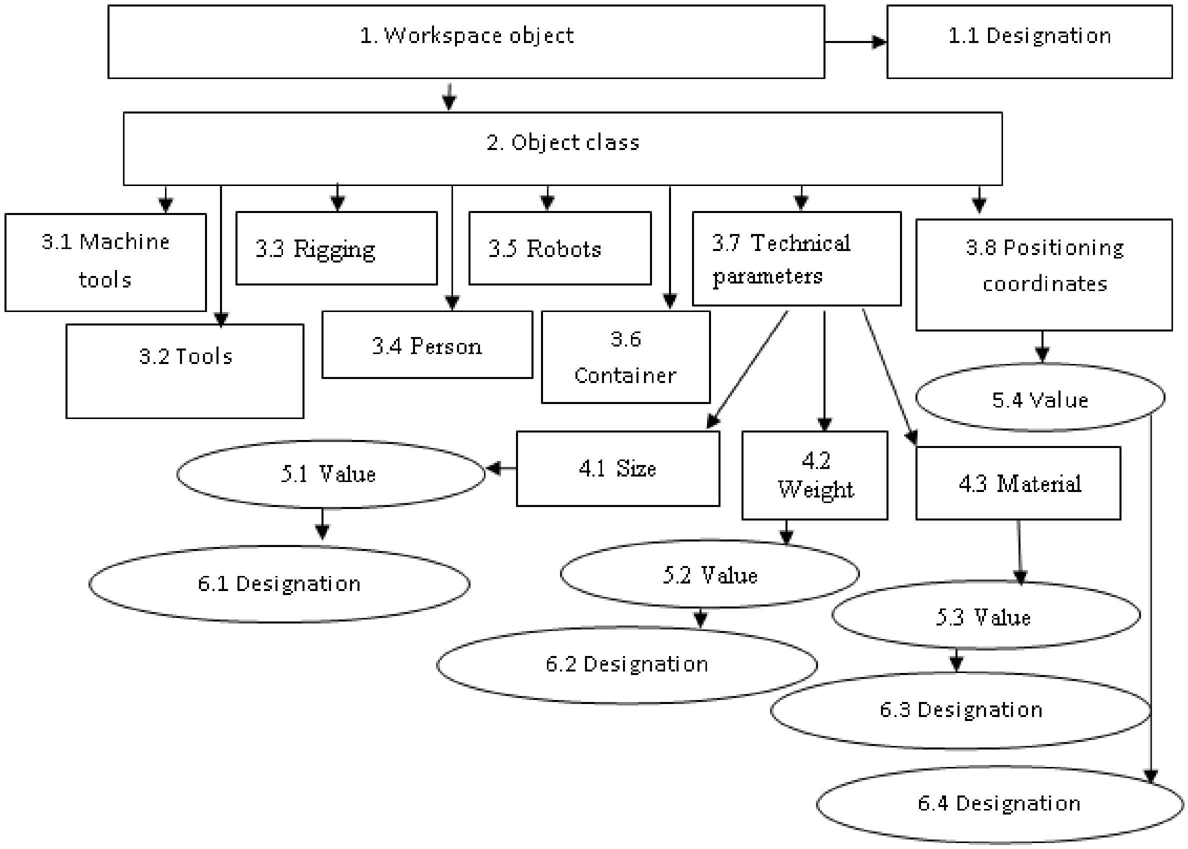


Figure 4. Structural elements of semantic network of industrial robot's workspace

Fig. 4 it can be seen that network objects include six levels of hierarchy.

The proposed hierarchy will be basis for creating a semantic model of classification elements of industrial robot's workspace, which consists of:

1. Descriptions of nodes properties. Property – elements of information that describe a node (object).

2. Descriptions of connections and their types. Formally, semantic model of industrial robot workspace can be represented by heterogeneous n-ary semantic network:

$$WS = \{Nd, Rel\},$$

where:

Nd – network nodes set;

Rel – relationships set.

Set of nodes in proposed semantic network can be described in form of following properties:

$$Nd = \{Name, OType, SType\},$$

where:

$Name$ – text string (matches node);

$OType$ – object type (corresponds to node);

$SType$ – semantic type of object (corresponds to node).

The set of links in proposed semantic network can be represented by link type property:

$$Rel = \{TypeRel\}.$$

Initially, in structure of semantic network, we select key object and "periphery" (elements related to key object, etc.), thus:

$$OType = \{KeyO, Con, ConG, KT\},$$

where:

$KeyO$ – key concept;

Con – concept;

$ConG$ – concept group; CT – context (building relationships between entities using hierarchical contexts).

Semantic type $SType$ is a semantic feature that unites network objects:

$$SType = \{Being, Item, Name, Num\},$$

where:

Being – essence (living being);

Item – subject, material;

Name – object name, text string (required for text description). For example, designation of a workspace object contains text string Name, and may also contain numeric values Num (marking, etc.);

Num – number (numeric value) that describes dimensions, mass, positioning coordinates.

Next, it is necessary to describe types of links used to build semantic network (Rel):

$$TypeRel = \{Atr, Agr, Dep\},$$

where:

Atr – attributes (lower-level object of hierarchy is an attribute (clarifying, revealing essence) of upper-level object. This type of relationship is most frequently used;

Agr – aggregation (or belonging to a class), where aggregation – expresses concentration of several lower-level elements into a single (one) upper-level element or dividing one upper-level element into several homogeneous lower-level elements. Class membership – elements of one level belong to an element (one) of another level;

Dep – dependence between objects, for example, description of dimension values depends on designations of these dimensions (you can set height to designate H, etc.). Such communication can be between objects of same level, it can be bi-directional.

As a result, proposed in fig. 4, hierarchy of structural elements will be used to develop a semantic model of objects in working space of industrial robots (fig. 5).

The first element of the model – node / object (can also be called an entity) in model is denoted by rectangle.

Second element of model is connection between nodes (we will express it through semantic type – semantic feature that unites nodes of network).

Link types are described above.

In work, type of connection has been selected for its intended purpose – classifying – that is, links describe various hierarchical relationships between nodes, and there are also functional ones – computational models that allow describing procedures for calculating some information units through others [17] and scenarios – are used to describe casual relations (causal or determining influence of some phenomena or facts on others), as well as relations of type "means – result", "instrument – action", etc. [18], [24].

According to degree of elements participation in links – an n-ary semantic network.

The proposed semantic network is designed to solve a specific problem.

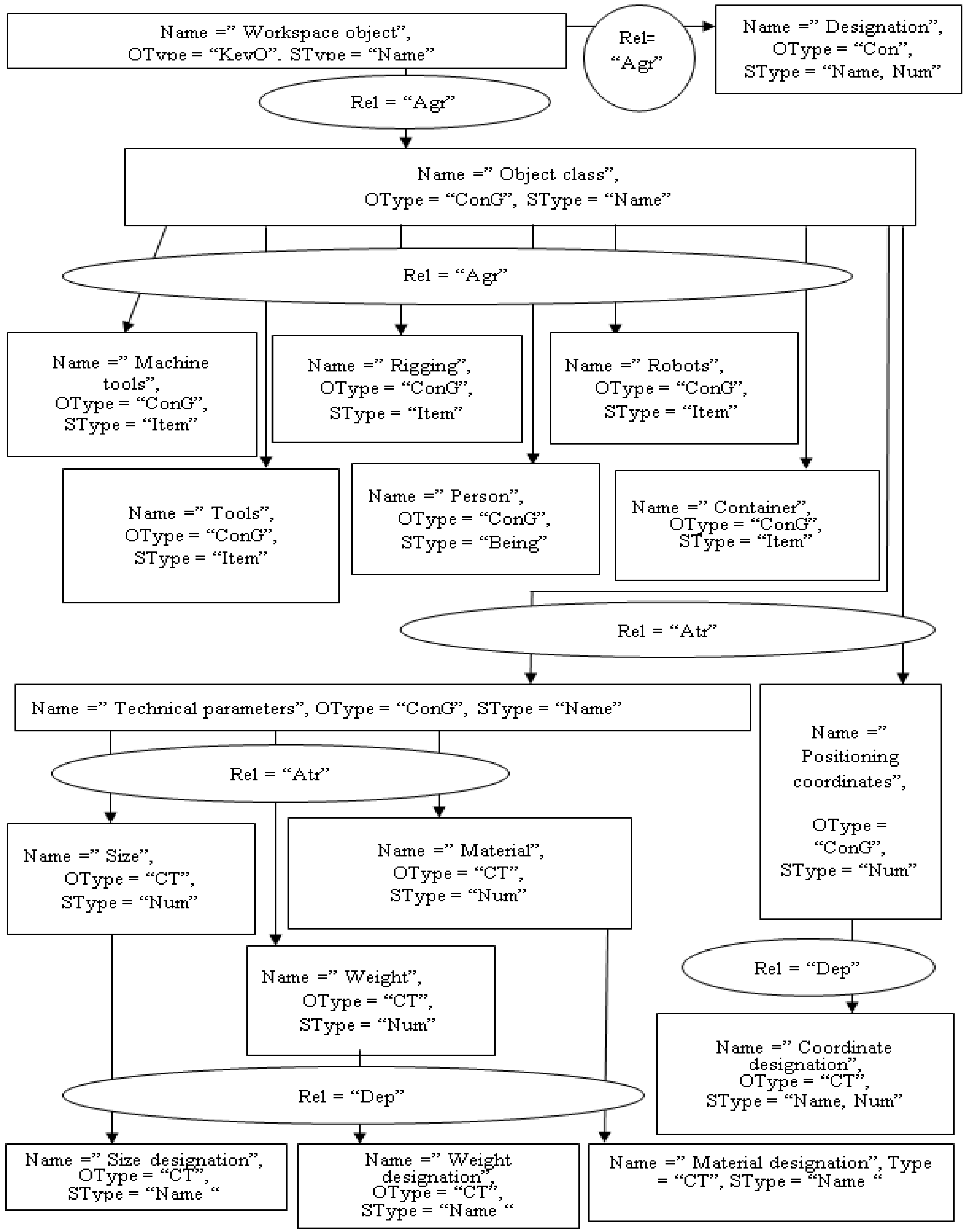


Figure 5. Semantic model for describing classification properties of objects in working space of industrial robots

These are models of dynamic semantic hierarchy, that is, data model and semantics of objects with dynamic roles (entered data can change and also be replenished), for example, positioning coordinates, for example, person, as an object of industrial robot's workspace, can change over time.

5. Conclusion

This paper presents fundamental formal definition of semantic network objects. Advantages and disadvantages of using semantic networks for describing objects of industrial robot's workspace are determined.

Three types of semantic networks structures are given. A generalized algorithm for constructing domain model in form of semantic network is considered.

As a result, structural elements hierarchy of semantic network of industrial robot's workspace was created on basis of which a semantic model for describing classification properties of objects in working space was built. In course of building model, objects types, nodes semantic features, their attributes were determined, types of links between objects were determined.

The semantic model will make it possible to describe relationship of objects in workspace, which will help to avoid collisions of robots with objects in its space in future.

Also, proposed model can become basis for structuring information when developing database of an archive of standard solutions and knowledge base for information support for search procedures in an archive of workspace objects.

It can also be used to analyze dynamic systems and processes.

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