Open Integrated Semantic Component Design Technology

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***Abstract*—The Digital revolution in industry is supposed to cover all stages of the product life cycle, including product design and planning of manufacturing processes. At these stages, goods and processes are not accomplished as real things but formed as models in the virtual world. Therefore, the Internet of Things concept, the basis of the "Industry 4.0" project, is not sufficient to conduct a full-scale digital revolution.**

The key methodology to examine this problem is the methodology of artificial intelligence. It provides for comprehensive consideration of the problems that arise at all stages of the life cycle of engineering products.

The Internet of Knowledge has an ontological basis and includes meta-ontology, which comprises the ontology of objects, the ontology of tasks and the ontology of optimization. The Digital Revolution should give the knowledge carriers without programming skills an opportunity to enter pieces of information into the computer without intermediaries. The materials of the paper are of practical value for the creation of integrated automation systems of engineering products design and production.

***Keywords*—digital manufacturing, intelligent systems, computer-aided process planning, computer-aided manufacturing, manufacturing execution system**

I. Introduction

Before the digital revolution, written sources were the bearers of knowledge. As a result of the digital revolution, software has become knowledge carriers. Software was originally built on an algorithmic basis using algorithmic languages. A non-programming knowledge carrier could not enter them into a computer. The digital revolution should radically change this scheme and enable a non-programming knowledge carrier to enter them into a computer without intermediaries. This became possible using the expert programming methodology [1, 2]. In this methodology, knowledge is described in the language of business prose, as close as possible to the literary language, but formalized so that it is possible to automatically generate software tools that correspond to the source texts. Below is an example of the use of expert programming.

II. Wikipedia and Expertopedia

The most common computer encyclopedia currently is Wikipedia (Fig. 1). Wikipedia is a publicly accessible multilingual universal Internet encyclopedia with free content [3]. Its conceptual principles are multilingualism and the ability of users to replenish and adjust the content. Encyclopedia is a review of all branches of human knowledge or a circle of disciplines brought into the system that together constitute a separate branch of knowledge. In this case, we are interested in the meta category "Technique". Only information on various devices, mechanisms and devices that do not exist in nature and are made by humans should be directly placed in this category.

Traditional wikis have a number of drawbacks, which include, in particular, lack of consistency in content. Due to the frequent duplication of data on wikis, the same information may be contained on several different pages. When changing this information on one wiki page, users should ensure that the data is also updated on all other pages.

Another drawback is the difficulty of accessing the knowledge available on wikis. Large wiki sites contain thousands of pages. Performing complex search queries and comparing information obtained from different pages is a task that is quite time-consuming in traditional wiki systems. The program can only show the text of a Wikipedia article in a certain context and cannot take additional steps related to the object.

Traditional wikis use flat classification systems (tags), or classifiers organized in taxonomy. The inability to use typed properties generates a huge number of tags or categories. In this regard, semantic wikis appeared (Fig. 1). Semantic Wiki is a web application that uses machine-processed data with strictly defined semantics in order to expand the functionality of a wiki system [4].

Regular wikis are populated with structured text and untyped hyperlinks. Semantic wikis allow you to specify the type of links between articles, the type of data within the articles, and page information (metadata).

A variety of such systems based on the technology of expert programming described below for creating knowledge bases can be called "Expertopedia" (Fig. 1).

The semantics of Expertopedia is determined by the

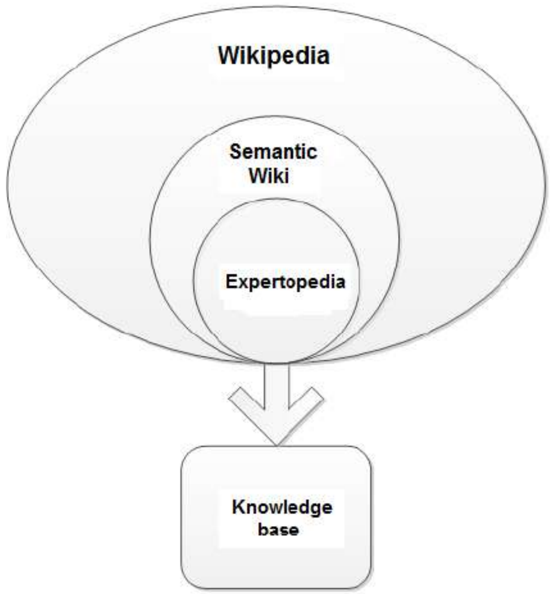

Figure 1: Wikipedia and Expertopedia

metaontology used in all cases. In this case, the root meta object is the knowledge base, which has its own name, identifier name, and version. The methods connected to the knowledge base allow you to sort and search the knowledge modules of which it consists. A subset of knowledge modules integrated into a semantic network is a method that can be exported to other knowledge bases, as well as imported and merged into a single semantic network.

From a wiki point of view, the knowledge base is a page. Moreover, the knowledge base can be considered as a module as part of the upstream knowledge base, which in this case consists of a set of pages. The structural components of a knowledge base are a knowledge base dictionary and many modules. The dictionary has its own identifier name and consists of words. It is possible to sort and search for words, as well as import words from text documents. Words also have an identifier name and a meaningful name in one of the languages of the world, as well as a type of word from a set of integers and real numbers and a set of characters. There are operations for adding, deleting and determining the occurrence of a word.

Words of an enumerated type can have associative lists containing valid word names. An associative list has an identifier name, a name, and a type of values from among the above. For lists, you can add, delete, sort values, and search for a list. The list consists of many elements with their values and the ability to add and remove values. The ability to replace the knowledge base dictionary allows for the fulfillment of the conceptual requirements of wiki systems: the use of any world language.

The second structural component of a knowledge base is a multitude of knowledge modules (KM). KMs perform the main functional purpose of the knowledge base - transforming the current state of the data in order to obtain new objects that satisfy design goals. Each module has a name, as well as identifier names of the module itself, preconditions for its execution and version.

The knowledge base has the ability to add modules, select an analog module, translate the knowledge module into one of the programming languages, test the result, as well as determine whether the module is in the knowledge base and delete the selected module. These actions can be performed by any operator, which allows you to implement the second conceptual basis of wiki systems: providing the possibility of independent replenishment and adjustment of the content of the system.

Each knowledge module has its own dictionary, which is a subset of the knowledge base dictionary. Due to the fact that modules are an object-function, the dictionary has two subsets: input and output variables of the module.

Knowledge modules can have preconditions that determine the possibilities of its implementation. Preconditions are logical expressions made up of words from a dictionary of a knowledge base, restrictions on the value of variables, and logical connectives.

The functions of the data conversion module are performed by mechanisms, which can be formulas, tables, working with databases, generating 3D models of objects, as well as mathematical models. When working with databases, it is necessary to select a database from among the available ones and the tables in it. Next, the access conditions are formed and the fields and properties used in the database and when creating the knowledge base are matched. The operation itself is performed by the corresponding DBMS.

It is possible to create and modify geometric 3D models based on the calculation results using the capabilities of various CAD systems. In this case, it is necessary to form a model and parameterize it.

Another variety of mathematical knowledge needed to perform calculations is models of continuous systems based on differential-algebraic systems of equations. To implement these capabilities, there must be a tool with the ability to generate the mentioned models. Such a tool should provide: support for object-oriented modeling technology compatible with the UML language; convenient and adequate description of the model in a generally accepted mathematical language without writing any program code; automatic construction of a computer model corresponding to a given mathematical model, with the possibility of autonomous use of this computer model.

To the greatest extent, these requirements are met by the Model Vision Studium (MVS) package [5]. The core element of the MVS language is the Active Dynamic

Object (ADO). An active dynamic MVS object provides modeling not only of continuous behavior, but also of a discrete or hybrid one. As noted above, semantic wikis allow you to specify the type of links between articles, the type of data within the articles, and information about pages (metadata). In Expertopedia, articles are knowledge bases that can go into one another in the form of knowledge modules.

III. Knowledge Base Examples

We will consider the formation of a knowledge base by the example of designing caps for bearings. The knowledge base consists of knowledge modules (MZ). Each module has input and output properties, as well as a mechanism for converting the first to the second. In this example, formulas and tables are used as mechanisms. Using knowledge tools, knowledge modules are converted into software tools, with the help of which in this example a 3D model of an object with calculated dimensions is generated (Fig. 2).

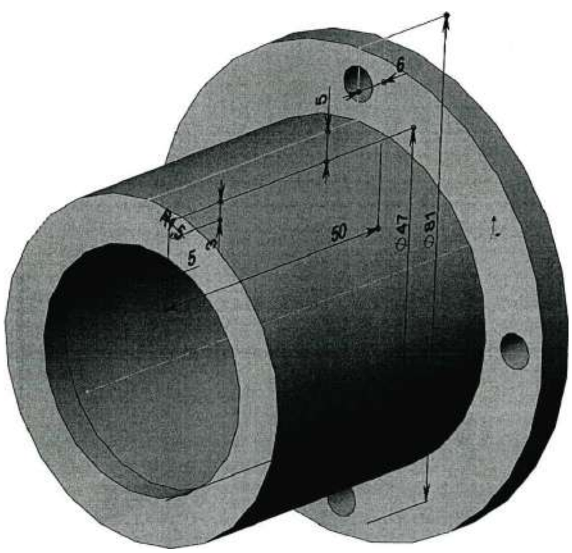

Figure 2: 3D model of the designed screw cap

Determining the design of the covers is the diameter D of the hole in the bearing housing 204 GOST 8338-75. Table I gives recommendations for choosing the wall thickness del, diameter d and number z of screws that secure the cover to the housing, depending on the D bearing:

Table I

D, mm	0...50	50...62	63...95	100...145	150...220
del, mm	5	6	8	10	12
d, mm	6	6	8	10	12
z	4	4	4	6	6

Dimensions of other structural elements of the cover: del2 = 1.2 * del; del1 del Dph = D + (4 ... 4, 4) d; C d.

MZ: "FORMULA" — Calculation of the size of the bearing cap

Input properties

Name	Description	Type	Value
D	Bearing diameter	REAL	47
dh	Hole diameter	REAL	6
r_	Bearing radius	REAL	1.5
del	Side wall thickness	REAL	5

Mechanism — Formula

dell=del
del2=1.2*del
Da=D+2*del
Df=Da+4*dh
C_=dh
t_=2*r_

Output Properties

Name	**Description**	**Type**	**Value**
C_	The distance from the side wall to the centers of the holes	REAL	6
t_	Thrust Shoulder Height	REAL	3
Df	Flange diameter	REAL	81
del1	End wall thickness	REAL	5
del2	Flange thickness	REAL	6
Da	Outside Diameter	REAL	57

MZ: "tabledel" — Selection of bearing cap sizes

Input Properties

Name	**Description**	**Type**	**Value**
D	Bearing diameter	REAL	47

Mechanism — Table

Table property configuration

D
Del
Dh
Z
r

Table

(0,50)	(50, 62]	[63, 95]	[100,130]	(130,145]	[150,220]
5	6	8	10	10	12
6	6	8	10	10	12
4	4	4	6	6	6
1.5	1.5	2	1.5	3	3.5

Output Properties

Name	**Description**	**Type**	**Value**
Z	Number of holes	INTEGER	4
r	Bearing radius	REAL	1.5
del	Side wall thickness	REAL	5
dh	Hole diameter	REAL	6

IV. Results

In order to integrate the Industrial and Digital revolutions that are taking place at present, it is necessary to consider two worlds together: the virtual world realized by the Internet of Knowledge (IoK), and the real world realized by the Internet of Things (IoT).

The Internet of Knowledge has an ontological basis and includes meta-ontology, which comprises the ontology of objects, the ontology of tasks and the ontology of optimization.

The Digital revolution should enable the non-programming knowledge carriers to enter knowledge into the computer without intermediaries. That can be done by way of expert programming methodology, in which knowledge is described in the language of business prose, which is very close to the literary language, but formalized so that it becomes possible to automatically generate software matching the source texts. Business prose can be formed in any languages, and software can be generated in different programming languages.

Artificial intelligence methods allow creating semi-automated systems for products' 3D model generation using knowledge bases integrated with CAD systems. It should be possible to integrate them with various CAD systems.

Knowledge bases are generated on the basis of knowledge modules representing a condition-action rule, which has an identifier and name, a precondition, input and output properties, and a mechanism for converting the first to the second. Modules are automatically translated into subprograms in the programming language selected by the user. Thus, the user can choose both the input language of the knowledge representation and the resulting language of the software generation.

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Открытая интегрированная технология компонентного проектирования

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Предложена методология создания семантических вики-систем для представления знаний с использованием технологий искусственного интеллекта. Методология основана на многоагентных методах создания баз знаний и пригодна для разработки систем проектирования и управления для цифровых интеллектуальных производств. При формировании внешнего представления баз знаний могут использоваться национальные языки. Проанализированы схемы ввода знаний в компьютер. На основе технологии экспертного программирования для создания баз знаний предложена семантическая вики-система, которая может быть названа «Экспертопедией». Возможность замены словаря базы знаний позволяет обеспечить выполнение концептуального требования викисистем: использование любых языков. В базе знаний имеются возможности добавления модулей, выбора модуля-аналога, трансляции модуля знаний на один из языков программирования, тестирования полученного результата, а также определения входимости модуля в базы знаний и удаления выбранного модуля. Эти действия могут выполняться любым носителем знаний, что позволяет реализовать вторую концептуальную основу вики-систем: обеспечение возможности независимого пополнения и корректирования содержания системы. Разработана метаонтология Экспертопедии. Подробно рассмотрены методы создания многоагентных баз знаний для проектирования и управления в машиностроении. Приведена архитектура агента САПР. Даны примеры применения многоагентных систем для создания интеллектуальных систем полуавтоматического проектирования изделий машиностроения. Описана технология экспертного программирования.

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