Abstract

The software, information, methodical and intellectual support of the equipment operation provision is a critical issue to guarantee the success of enterprises. This paper devoted to the more efficient use of expert knowledge in the field of maintenance and repair of equipment, through the development of ontologies of different technical systems and algorithms to work with them. Developed ontology of road construction machinery, office equipment, maintenance services and contractors shown. Described the process of combining classifiers for industrial equipment. Showed generating circuit files of ontology-based text analysis classifier of fixed assets. The algorithms use methods and derived models. After construction and filling of the respective ontologies were formulated a set of tasks to work with them, and we get algorithms work with them. This paper brings a contribution to increasing of performance of equipment maintenance.

Keywords: artificial intelligence; ontological engineering; decision support; maintenance and repair; equipment maintenance; life cycle modeling.
1. Introduction

Competently carry out maintenance and repair is a rather difficult task, thus employees are guided by their experience and knowledge acquired over many years. The more knowledge they have, the more benefit they do for the company, which, in turn, improves the quality of work, meeting the demands of consumers\textsuperscript{1,2}.

The concept of "knowledge" has been long widely used in education, science and other spheres of human activity. However, a clear and generally accepted definition does not currently exist\textsuperscript{3,4}. It happens because each subject area has its own "specific" knowledge. In modern literature, there are different definitions of the term "knowledge".

Knowledge of maintenance are divided into implicit and explicit. Hidden knowledge (personal experience, education, etc.) are stored in the heads of employees. Explicit knowledge is formalized, encoded on natural or artificial languages and can be transferred. All the knowledge of the organization is represented as distributed knowledge base, which is manifested in the environment of the business processes and in the form of objects of knowledge. These objects include agents (individuals and groups) and artifacts (documents, books, computer systems, etc.). The agents contain subjective knowledge, i.e. hidden, while the artifacts contain objective knowledge, presented in the form of an explicit, coded linguistic expression. Objects of knowledge can be considered as the interface between the processing results of knowledge and the runtime of the business processes in which decisions and actions are performed by the employees of the organization in the implementation of production tasks\textsuperscript{5}.

Implicit knowledge is the most interesting in a production environment. However, this knowledge is harder to get. Organizations are becoming more competitive due to the preservation and enhancement of knowledge potential. In this connection, it’s actual to create a knowledge management system.

Generally, knowledge management is a clear procedure that is established in the organization for working with information and knowledge resources and expertise in certain areas to facilitate access to knowledge and reuse of data by means of modern information technologies\textsuperscript{6,7}.

There are two general approaches to the construction of knowledge management systems (KMS). The first (classic) - KMS is based on combining existing, proven technologies to support the various sub-processes of working with knowledge. It is a standard and widely used technology, such as E-mail, bulletin boards, discussion forums, shared documents directory, portals, metadata, and specific technologies, gravitating towards the artificial intelligence tools, such as automatic classification, automatic annotation of documents, pattern recognition and speech, etc\textsuperscript{8}.

The second approach is defined as semantic. It is based on the use of interrelated set of methods and technologies to work with meaning, semantics of data, information and knowledge. It includes: domain ontologies, the technology of their construction and maintenance, semantic metadata, semantic search, inference systems, semantic profiling of expert knowledge, semantic portals and networks, etc., with appropriate technological support for markup languages, models, software tools and systems\textsuperscript{9}. This semantic approach does not reject classical. Most of the elements and instruments of the classical approach are put into the set of tools of developed corporate information systems, which are used to increase the level of data and information.

A continuous process of movement of knowledge is a process of production, compilation and dissemination of knowledge in every organization, regardless of the scope of its activities\textsuperscript{10,11}.

Nowadays, the main volume of structured data sources are relational databases, although it can be a file system, XML database, expanding the scope of their application, and other types of information sources. Regardless of the chosen method of data storage, the first problem of integrating heterogeneous data to be faced when forming a corporate repository (repository) of information resources, the diversity of models and data schemas, their low level of abstraction, small adequacy reflect the semantics of the subject area. In this case, a good solution is to move some object-oriented data model, based on ontologies, which are in many respects close to semantic models, where the Central unit is complexly structured information object (the image) that support various attributes (in particular, for Executive and expert data schemas) participating in various associations with other objects\textsuperscript{12}.

In engineering knowledge under the ontology (conceptual specification) the detailed description of some of the problem area is meant, which is used for formal and declarative definition of its conceptualization. We can say that ontology is a precise specification of some area, which includes a Glossary of terms of this area and many logical connections (type "element-class", "part-whole") which describe how these terms relate to each other. You may
notice that in this approach the notion of ontology is strongly overlaps with an already accepted in computer science and linguistics concept thesaurus\textsuperscript{13, 14}.

Ontologies are used as an intermediary between the user and the software system; they allow formalizing agreement on terminology between users of a corporate data warehouse automated system for product data management. Ontologies provide consistency and synchronisation of changes to the underlying data with all enterprise information systems. This typical design solution enables centralized management of master data in the corporate reference\textsuperscript{15}.

The top-level ontology organize mandatory user interaction with industry standard reference database and enterprise standards.

Standard ontologies are developed in many disciplines now. Experts in the subject areas (domains) can use these ontologies to share and annotate information in their fields.

While developing an integrated system of ontology in engineering it would be advisable to create a general-purpose ontology, including description of requirements to the product, in particular:

- the composition of the product;
- assignment requirements;
- electronic protection requirements;
- requirements survivability and resistance to external influences;
- reliability requirements;
- ergonomic considerations, habitability and technical aesthetics;
- requirements for operation, storage, ease of maintenance and repair;
- transportability requirements;
- safety requirements;
- protection requirements;
- requirements of standardization, unification and cataloguing;
- requirements of manufacturability;
- design requirements.

This ontology used by a particular application program and containing terms that are used when developing software which performs a specific task on the design of technological or operational documentation\textsuperscript{16, 17}. It reflects the specifics of the application, but may also contain some General terms (for example, specific requirements for completing forms, online documents, and General - save and upload the file).

The domain ontology and task ontology describe, respectively, dictionaries, which relate to a particular subject area by aspects (e.g. design, engineering, diagnostics, Metrology, etc.) or a typical problem, for example, a typical production process.

They use specialized terms that are introduce in the top-level ontologies.

Application ontologies describe concepts that depend on the task ontology and domain ontology. An example ontology for automobiles, building materials, computers. The domain ontology generalizes the notions used in some domain tasks, abstracting from the tasks themselves (so, ontology prototype of artillery weapons independent of any characteristics of the particular brands designs)\textsuperscript{18}.

The domain ontology can be used as the basis for building a knowledge base of intelligent information systems, which allows it to use when making decisions in the field of technical service. This greatly simplifies the analysis of knowledge in the subject area and allows using the data again. The knowledge management system provides control of the following processes: the creation of new knowledge; the use of existing knowledge when making decisions; the embodiment of knowledge in products and services; providing access to relevant knowledge. Thus, from the point of view of knowledge management, the essence of KMS lies in its potential to create, transfer, integration and exploitation of knowledge assets\textsuperscript{19}.

The objectives of work are:

- Conduct research and develop models of knowledge representation on industrial equipment.
- Develop ontology: road construction machines, electrical systems, office equipment, ventilation systems, control and diagnostic systems, repair and construction services, general industrial equipment.
- Develop expert system for faults diagnosis in machine/node, and creation a production knowledge base for diagnostic of office equipment faults.
2. The developed model of equipment knowledge representation

In accordance with the objectives of the work, we developed models of knowledge representation on industrial equipment, road construction machines, electrical systems, office equipment and office equipment, the elements of the process of its operation and the methods of effective management of equipment operation. Carried out the construction and filling of the respective ontologies formulated a set of tasks, the resulting algorithms. Detailed composition of the task of supporting the operation of the equipment: monitoring equipment status, decision-making strategies and tasks of maintenance and repair of technical systems, rational use of resources in the operation of equipment at various stages of the life cycle of technical systems.

Sophisticated algorithms are methods of using the developed models; produced by testing models and methods in subject areas related to the organization of the operation of industrial equipment, road building machinery, electrical systems, office equipment and office equipment, and other technical systems.

Road construction machinery is a group of machines for construction works, as well as for the operation and maintenance of roads. Despite the widespread use of the term, "construction machinery" is not well established. Also used the term "road-building machines."

Types of road construction machinery:
- machines for preparatory works;
- earth-moving machinery;
- machines for soil compaction;
- machines for the production and transport of concrete mixtures;
- mineral processing equipment;
- machines for construction of artificial structures;
- snowplows and machines for cleaning roads;
- and others.

Fig.1 shows the ontology of road-building machines.
Fig. 2 shows the ontology of office equipment. Ontology of office equipment can be use as the basis for a set of tools for managing the office store: the category of office equipment for the current day or unresponsive administrators and store buyers.

For all kinds of work on the establishment of maintenance and repair enterprises, repair facilities created the ontology. It includes works general craft and repair services for large enterprises, repair facilities centralized at the enterprise level. Fig. 3 presents the ontology of repair services and contractors.

The final ontology of general industrial equipment contains about 450 classes. The ontology based on the American system NAICS (section 3339) and on the Russian classifier OCOF (or OKOF) of fixed assets (section 14). The integration of the two classifiers held in semi-automatic mode. For translation of OCOF in the ontology format developed the program, which algorithm is shown by Fig. 4.
Fig. 3. The class diagram of repair services and contractors ontology in the notation of IDEF5.

Fig. 4 shows a block diagram of the algorithm of the program translation classifier of OCOF in the ontology format and merge it with the ontology of the industrial equipment.

Automatic merging of ontologies is intended to fully match class names ontologies. As a result of the program no matches are found.

From the difference in structure and approach of building OCOF and industrial equipment, it was necessary to develop a semantic comparison of classes and module evaluation of their similarity. Just different groups of data (OCOF on the grounds of the destination, and industrial equipment according to the type of equipment).
3. Conclusions & Implications

A representation model of knowledge about general industrial equipment developed. The ontology of General industrial equipment contains about 450 classes. The ontology based on the American system NAICS and on the Russian classifier OCOF of fixed assets.

As result of the execution of this work were designed:
- Description of the representation of knowledge about the structure and functioning of technical systems that store and process information (data and knowledge) throughout the life cycle of the system to support their efficient, reliable and high-quality operation;
• The ontological model of branch systems for support the operation of the equipment (General industry, construction equipment, office equipment, electrical engineering, and others).
• The algorithms of methods of use of the obtained models.

This paper brings a contribution to increasing of performance of equipment maintenance.

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