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Problem-Oriented Corporate Knowledge Base Models on the Case-Based Reasoning Approach Basis

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Abstract. One of the urgent directions of efficiency enhancement of production processes and enterprises activities management is creation and use of corporate knowledge bases. The article suggests a concept of problem-oriented corporate knowledge bases (PO CKB), in which knowledge is arranged around possible problem situations and represents a tool for making and implementing decisions in such situations. For knowledge representation in PO CKB a case-based reasoning approach is encouraged to use. Under this approach, the content of a case as a knowledge base component has been defined; based on the situation tree a PO CKB knowledge model has been developed, in which the knowledge about typical situations as well as specific examples of situations and solutions have been represented. A generalized problem-oriented corporate knowledge base structural chart and possible modes of its operation have been suggested. The obtained models allow creating and using corporate knowledge bases for support of decision making and implementing, training, staff skill upgrading and analysis of the decisions taken. The universal interpretation of terms "situation" and "solution" adopted in the work allows using the suggested models to develop problem-oriented corporate knowledge bases in different subject domains. It has been suggested to use the developed models for making corporate knowledge bases of the enterprises that operate engineer systems and networks at large production facilities.

1. Introduction

In recent decades one of the important directions of production processes automation development and activity management of enterprises of different areas has become a development of corporate knowledge systems [1-7]. Corporate knowledge bases (CKB) allow saving and use of the knowledge, available to the enterprise collective, for many tasks: from new product design and production to provision of commercial activities and managerial decision making.

Despite the urgent character of knowledge management systems there are still no single technological solutions to build CKB. An approach, popular today, uses content management systems (CMS), where knowledge can be represented in the form of texts, images and other content components created by corporation employees [7-9]. A corporate knowledge base obtained as a result of such an interaction, is represented by a network with a variety of semantic ties and associations which do not often lend themselves to precise definitions.

Due to the diversity of ties and content components and lack of the clearly defined task-oriented structure it is difficult to search and use knowledge to solve specific problems that may arise before users at an enterprise. As a consequence there is a reduction of CKB effectiveness and doubt about the usefulness of the knowledge management system as a whole.
This article suggests a new conceptual model – a model of problem-oriented corporate knowledge bases (PO CKB) – which allows making the system of enterprise knowledge more constructive and task oriented.

In PO CKB corporate knowledge (content) are arranged around problem situations that arise during the corporation (enterprise) activities.

These situations are characterized by the fact that a) in the current situation, the obvious and only mode of action is missing; b) the situation requires creative decision-making from the staff, which is associated with options generation and analysis; c) the execution of these decisions involves a set of actions and documents and is carried out in accordance with definite, possibly various scenarios.

The basic idea of CKB, oriented to problem situations, is to create a system that will provide the knowledge for making and implementing decisions in such situations (ready-made decisions, actions scenarios, regulatory documents, specifications, cost estimates, contract templates, etc.).

Problem-oriented CKB allows not only to support the decision makers, but to use the corporate knowledge and experience for training, skill upgrading and commissioning of new employees, as well as to make corporation activity results retrospective analysis.

Further on a domain-independent knowledge representation model to implement this concept has been suggested and a generalized PO CKB structural chart has been developed.

2. Method and models

2.1. Case-based reasoning

A theoretical basis of building problem-oriented CKB is the case-based reasoning method in intelligent systems [10, 11].

The basic idea of CBR is to solve emerging problems using the decisions already known from the past experience which were previously used in practice or were suggested by experts for similar problems.

The knowledge bases components in CBR systems are cases that are stored in a case-base (CB) (library).

Each case is represented by the couple <Situation, Solution>. Under the situation a formalized description of a problem to be solved is meant.

In a general case anything that can be used or recommended in this situation is represented as the solution.

The work of the CBR-system includes the following major stages [12]:
- «retrieve» – search and selection of the case which is most suitable for solving a current problem in CB. The search key is the description of the current user situation Sit, which is compared with situations S from the case-base. At the end of this stage one or more S* which are most similar to situation Sit are selected;
- «reuse» – retrieving and reusing of solution R*, which enters the same case as S*.

If necessary, solution R* is adapted to a new situation. If a new solution for a new problem was obtained, after the results auditing the new case is added to the CB.

Case base reasoning to find solutions has shown its effectiveness in different problem areas. For example, this method is used for traffic control at crossroads [13], in software development support systems [14], to identify damages and predict mechanical systems states [15, 16], for text classification [17], in medical systems [18-21] to predict the cost of construction [22, 23], etc.

The assessment of closeness of situations Sit to S at the stage of «retrieve» is one of the most important tasks in CBR. The solution to this problem depends on the chosen method of formalized representation of situations. There are two main approaches to compare situations [11] – selection of the most similar situations based on distance measurement in the parameter space, and selection of situations based on the decision tree.

The work [24] suggests a decision tree modification – the situations tree (ST), which further will be complemented with new elements specifically for knowledge representation in PO CKB.
The situations tree is a binary ratio graph \( \rho(S_j, S_{j+1}) \) "type-subtype", where situation \( S_{j+1} \) at the \( (j+1) \)-th level is a description elaboration of situation \( S_j \) located at the previous, \( j \)-th level. This means that the set of attributes – indicators of situation \( A_j \) are included in set \( A_{j+1} \) of description of situations at the next level.

In this case two situations, \( S_j^i \) and \( S_j^r \), of the same level differ in the regions of the allowed values in the parameters space \( A_j^i \subseteq D_j^i \), \( A_j^r \subseteq D_j^r \), where \( D_j^i \neq D_j^r \).

The peculiarity of the situations tree is that its tops at each level are not abstract sets of variables, but correspond to some practically relevant types of situations. Each of them can match with its decision. The decisions at the upper levels have a higher level of generalization and are less detailed than the decisions at lower levels, but true for all situations, subtypes of the given situation of the top level.

2.2. PO CKB model of knowledge

In CBR-based problem-oriented CKB a case-base is a knowledge base. A formalized knowledge model is designed for domain-independent case view, the interrelations between them, as well as for case search and selection. When building such a model in PO CKB, we consider the following features:

- in enterprise activity there can be identified typical, recurring problem situations. They are characterized by a common set of features, some of which are relevant to the classification of situations, and others determine the problem context (specifies the place and time of occurrence, external conditions, decision executer, etc.);

- in these situations the solutions and the results can differ. The solutions effectiveness is estimated by experts based on subsequent analysis of the results;

- in the corporate knowledge base examples of situations and their solutions should be saved as well as some generalizations, i.e. descriptions of typical situations and typical solutions, which include activity templates, documents, typical scenarios, etc.

Thus, situations-examples will be distinguished from typical situations in CKB. A typical situation is characterized by field \( D \) of possible values of the attributes vector, and situation-example – by a point in field \( D \).

The knowledge model in PO CKB, implemented based on the situations tree, should represent both typical situations and situations-examples related to them.

In the particular case the situations-examples are matched with the lower levels and the upper levels are used to obtain generalized solutions and a sequential search according to the values of attributes (see Figure 1). In a general case, many examples can be matched with each top \( S \).

Taking into consideration the above mentioned, case \( C \) in the case base is represented by the following set of components associated with the tops of the situations tree:

\[
C = \{S, R <SE, RE, P > | k = 1, ..., M\},
\]

where \( S \) is a description of a typical situation, given through a set of allowed values of attributes \( D = \{d_1, d_2, ..., d_n\} \), where \( n \) is the number of attributes-indicators of this situation;

\( R \) is a typical solution for this situation, which includes the following:

- \( R_1 \) is an imperative part – a guide to an action in this situation, and answers the question "What to do?”;

- \( R_2 \) is a regulatory and guidance part, and answers the question "How to do?”;

- \( R_3 \) is a reference part, additional information which may be required for decision implementation (reference data, illustrations, models, etc.), "Through what to do?”;

- \( R_4 \) is a recommendatory part that contains experts' recommendations of how to implement the proposed decisions;

\(<SE, RE, P >\) is an example of a situation of this type, the decision made in this situation and the result obtained, respectively.

\( M \) is a number of examples in a case.
To describe situations-examples in PO CKB and for advanced search capabilities in CB elaboration of the set of attributes is desirable [4]:

SE⇒ {A, AC, T, I }, where A is a vector of situation attributes-indicators, which allows relating the situation to the given type A = (a₁, a₂, …, aₙ)∈D; AC are additional attributes to describe the context which are not used in the identification of the type; T is a text meta-description of a situation; I – a graphic image of the situation (photo, illustration, picture cards, etc.).

In PO CKB situation Sit stands for a user situation – a certain situation interesting for the user. It could be a current problem situation, which requires an immediate solution, or a hypothetical situation, interesting for the purpose of teaching, or a situation from a corporation’s past experience.

In a general case the user lacks not only an accurate description of Sit but also full information about those attributes which values need to find out to compare with the examples in CB. In case-based reasoning this gives rise to the problem of Sit identification, which is complicated by an increase in the volume of CB and by the occurrence of situations with different sets of attributes-indicators. It can become a serious obstacle to the practical implementation of CBR systems.

The suggested model allows overcoming this difficulty by a sequential search through the situations tree from the top down. Here each top S of the tree represents the set of attributes that should be inquired for further movement. Thus, alongside the search on the tree the identification of Sit is performed, and in this case only those attributes are inquired that have a value for this type. Eventually, the search leads to the desired top S* with a set of allowed values D*, for which A(Sit)∈D* is performed, where A(Sit) is a vector of the user situation attributes values.
2.3. Structural model

Based on the developed knowledge model for case views, there has been suggested a generalized structural chart of PO CKB (Figure 2). Since at existing plants, as a rule, there are various databases and documents, PO CKB is implemented as an add-in to the existing corporate accounting systems and content management systems. The descriptions of the situations-examples and their solutions include references to the known data and the documents or procedures necessary to be obtain in the existing systems.

As shown in figure 2, apart from the end-user a cases base editor is required to replenish CB. The system provides the following basic modes:

- search on query: search of a typical situation and (or) subset of situations-examples by attribute values (search on situations tree); full-text search by textual description T, search by the graphic image of situation I;

- cases base training (replenishment). With emergence of new situations and new solutions a new case is added to the cases base or the existing case is updated. If this new situation-example is an example of a situation type already present in CB, then the existing case is added. If this is a new type situation, the description of a typical situation is added and a case with new examples is formed. In this case a new top should be added to the situations tree, and its location will be determined by the ties of the new typical situation with the already existing ones.
A monitoring subsystem and current situation analysis can be added to the structural model, which can automatically identify the situations that require interference by a given set of parameters coming from the accounting systems. This provides another mode of operation – "consulting system mode" in which the end-user will get ready-made cases to solve an arising problem.

2.4. Problem-oriented knowledge bases to operate engineer systems and networks.

Creation of enterprises corporate knowledge bases to maintain engineer systems of buildings and structures (heat, water and electricity supply, etc.) is a promising application of the developed models in production activities. Operation of engineer systems at large and especially distributed plants is related to complexity and diversity of the equipment, a high probability of emergency situations, and great influence of the service quality on the plant life. PO CKB of an operating organization contains segments – situations trees for each type of the engineer systems. On the upper levels a situations tree divides a number of situations into two classes: \( S_{1}^{1} \) - regular situations that require routine maintenance work; \( S_{1}^{2} \) - emergency situations which require urgent organizational and technical measures to eliminate accidents and their consequences.

On the lower levels of a situations tree every top S corresponds to cases C, which contain a description of the updated typical situations, the solution components R required to perform routine maintenance or emergency works, as well as examples of situations SE, activities RE and the results of their performance P that took place in practice.

Occurrence of CKB allows consolidating and using the enterprise experience for both effective elimination of emergency situations and performing routine maintenance, as well as making an analysis of the staff activities.

3. Conclusion

In this work, we have suggested a concept of problem-oriented corporate knowledge bases, where knowledge is arranged around problem situations arising in a corporation, and is used to support decisions making and execution in these situations.

To develop a model of knowledge representation in PO CKB, we have used a case-based reasoning approach. As a result of the study a case view structure has been suggested. It contains descriptions of a typical situation, standard solutions, as well as specific situations-examples and solutions-examples. For storage arrangement and case search a knowledge representation model based on the situations tree and invariant to subject domain, has been suggested.

The universal interpretation of terms "situation" and "solution" admitted in the work allows use of the suggested models for the development of PO CKB and support of decisions in various subject domains. One of the promising directions is creation of corporate knowledge bases to maintain and operate engineer systems in buildings and structures of large productive facilities.

Apart from the very decision support database cases can be used for retrospective analysis of the corporation activities, staff training and expansion of corporation best practices.

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