Bibliography

[1] V.L.Stefanuk. Dynamic Expert Systems. The International Journal of Systems & Cybernetics. V. 29, Issue 5, pp. 702-709, MCB University Press, 2000.

[2] M.Mesarovich, Ya.Takakhara. General Theory of Systems: Mathematical Foundations. Moscow: Mir, 1978 (in Russian).

[3] G.S.Osipov. Dynamics in Integrated Knowledge-Based Systems. Proc. of the 1998 IEEE International Symposium on Intelligent Control (September 14-17,1998). Gaithersburg, Maryland, USA, 1998, pp.199-2003.

[4] T.G.Lebedeva, G.S.Osipov. Architecture and Controllability of Knowledge-Based Discrete Dynamical Systems. Journal of Computer and System Sciences International. NY, Vol. 39, No.5, 2000.

[5] N.Nilson. Principles of Artificial Intelligence. Moscow: Radio i svyaz', 1985.

[6] A.N.Vinogradov, L..Yu.Zhilyakova, and G.S.Osipov. Dynamic Intelligent Systems: II. Computer Simulation of Task-Oriented Behavior. Journal of Computer and System Sciences International. NY, Vol. 42, No. 1, 2003

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CASE-BASED REASONING METHOD FOR REAL-TIME EXPERT DIAGNOSTICS SYSTEMS

Alexander Eremeev, Pavel Varshavskiy

Abstract: The method of case-based reasoning for a solution of problems of real-time diagnostics and forecasting in intelligent decision support systems (IDSS) is considered. Special attention is drawn to case library structure for real-time IDSS (RT IDSS) and algorithm of k-nearest neighbors type. This work was supported by RFBR.

Keywords: Intelligent decision support systems, expert diagnostics systems, analogous reasoning, case-based reasoning.

ACM Classification Keywords: H.4.2 [Information systems applications]: Types of systems – Decision support; I.2.5 [Artificial intelligence]: Programming Languages and Software – Expert system tools and techniques; I.2.6 [Artificial intelligence]: Learning – Analogies.

Introduction

The problem of human reasoning simulating (so called "common sense" reasoning) in artificial intelligence (AI) systems and especially in IDSS is very actual nowadays [1,2]. That is why special attention is turned to case-based and analogous reasoning methods and models. The analogy and precedents (cases) can be used in various applications of AI and for solving various problems [3-7], e.g., for diagnostics and forecasting or for machine learning. AI experts model case-based reasoning by computers in order to develop more flexible models of search for solutions and learning.

In this paper, we consider method of case-based reasoning for a solution of problems of real-time diagnostics and forecasting in RT IDSS [5]. These systems are usually characterized by strict constraints on the duration of the search for the solution. One should note that, when involving models of case-based and analogous reasoning in RT IDSS, it is necessary to take into account a number of the following requirements to systems of this kind [2]:

– The necessity of obtaining a solution under time constraints defined by real controlled process;

- The necessity of taking into account time in describing the problem situation and in the course of the search for a solution;
- The impossibility of obtaining all objective information related to a decision and, in accordance with this, the use of subjective expert information;
- Multiple variants of a search, the necessity to apply methods of plausible (fuzzy) search for solutions with active participation of a decision making person (DMP);
- Nondeterminism, the possibility of correction and introduction of additional information in the knowledge base of the system.

The methods of case-based reasoning may be applied in units of analysis of the problem situation, search for solutions, learning, adaptation and modification, modeling and forecasting. The use of the respective methods in IDSS broadens the possibilities of IDSS and increases the efficiency of making decisions in various problem (abnormal) situations.

Case-based reasoning

Case-based reasoning, like analogous reasoning, is based on analogy; however, there are certain differences in their implementation [5, 8]. In the most encyclopedias, a precedent (from Latin, precedentis) is defined as a case that took place earlier and is an example or justification for subsequent events of this kind. To create a precedent means to give grounds for similar cases in the future, and to establish a precedent is to find a similar case in the past.

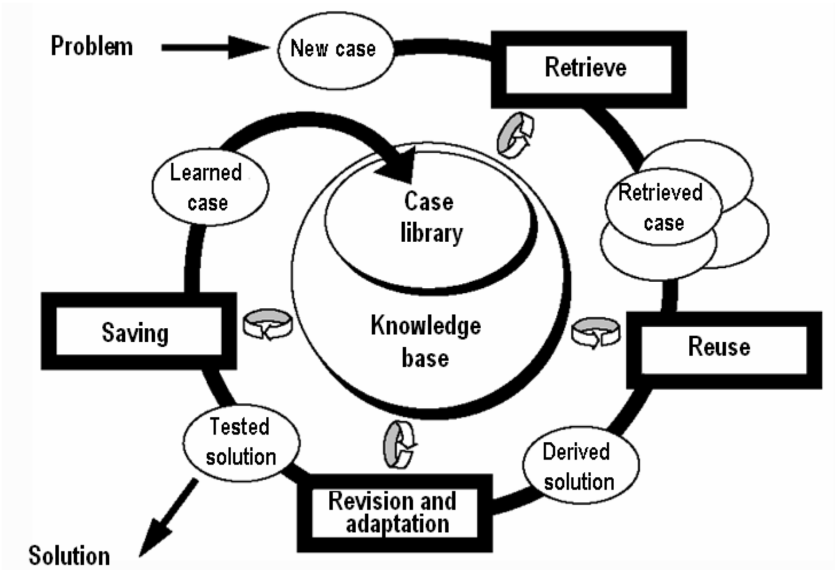


Fig. 1 The structure of CBR-cycle

As the practice shows, when a new problem situation arises, it is reasonable to use this method of case-based reasoning without drawing an analogy. This is caused by the fact that humans operate with these reasoning schemes at the first stages, when they encounter a new unknown problem.

Case-based reasoning is an approach that allows one to solve a new problem using or adapting a solution of a similar well-known problem. As a rule, case-based reasoning methods include four main stages that form a CBR-cycle, the structure of which is represented in Fig. 1 [9].

The main stages are as follows:

- Retrieving the closest (most similar) case (or cases) for the situation from the case library;
- Using the retrieved case (precedent) for solving the current problem;
- If necessary, reconsidering and adaptation of the obtained result in accordance with the current problem;
- Saving the newly made solution as part of a new case.

It is necessary to take into account that a solution on the basis of cases may not attain the goal for the current situation, e.g., in the absence of a similar (analogous) case in the case library. This problem can be solved if one presupposes in the CBR-cycle the possibility to update the case library in the reasoning process (inference) [5, 8]. A more powerful (in detecting new facts or new information) method of reasoning by analogy is a means of updating case libraries. We also note that the elements of case-based reasoning may be used successfully in analogy-based reasoning methods; i.e., these methods successfully complement each other and their integration in IDSS is very promising.

Use of the mechanism of cases for RT IDSS consists in output of the decision to the operator (DMP) for the current situation on the basis of cases which is contained in system. As a rule, the last stage in a CBR-cycle is excluded and performed by the expert (DMP) because the case library should contain only reliable information confirmed by the expert. Reconsidering and adaptation of the taken decision is required seldom because the same object (subsystem) is considered.

The modified CBR-cycle for RT IDSS includes following stages:

- Retrieving the closest (most similar) case (or cases) for the situation from the case library;
- Using the retrieved case (precedent) for solving the current problem.

Case-based reasoning for IDSS consists in definition of similarity degree of the current situation with cases from case library. For definition of similarity degree, the nearest neighbor algorithm (k-nearest neighbors algorithm) is used [10].

The k-nearest neighbors algorithm

The class of selection algorithms used by the most CBR products is called nearest neighbor (k-nearest neighbors). Let's explain the work of algorithm on a simple example. Consider an item that has two attributes: a **temperature** and a **liquid level**. Let us draw all the items at diagram. On the one (x-axis) there is the temperature, say, from **10 – 50°C**, while other (y-axis) contain a value of **liquid level** (for simplicity, let's make the range **1000 – 5000 mm**).

In the library, there are two cases:

- **C_1: t = 30°C**, **h = 3500mm**;
- **C_2: t = 40°C**, **h = 1500mm**.

For the current situation (**Target**): **t = 20°C**, **h = 3000mm**.

If we plotted them on the chart, it might look like fig. 2.

Now we shall calculate the distance from the Target up to C_1 and C_2:

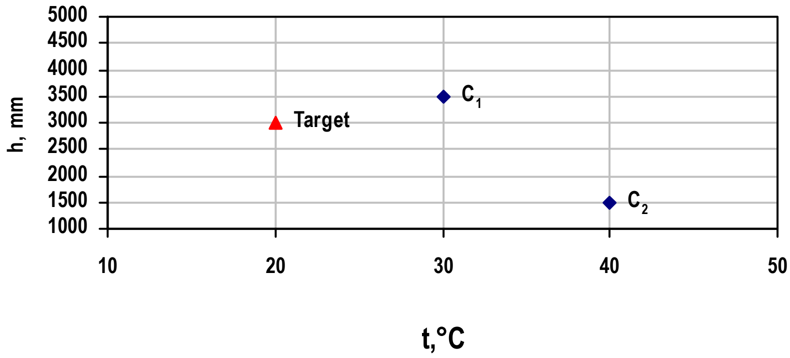


Fig. 2 Coordinate plane

$D_1 = \sqrt{(20 - 30)^2 + (3000 - 3500)^2}$ = 500,10; $D_2 = \sqrt{(20 - 40)^2 + (3000 - 1500)^2}$ = 1500,13.

The maximal distance D_{MAX} between points with coordinates (10,1000) and (50,5000) is similarly calculated (D_{MAX} = 4000,20).

Then values of similarity degree (SIM) of the current situation with two cases from case library are calculated:

- for C_1: $SIM_1=(1 – D_1/D_{MAX})$=(1 – 500,10/4000,20)=0,8750 (87,50%);
- for C_2: $SIM_2=(1 – D_2/D_{MAX})$=(1 – 1500,13/4000,20)=0,6250 (62,50%).

In case there are **n** (**n**>2) parameters for the description of a situation and cases, a more complex variant is considered, and it is differed from the presented one only that **n** coordinates are used.

Further, we shall view the structure of case library for RT IDSS on the basis of nonclassical logics for monitoring and control of complex objects like power units.

The structure of case library for RT IDSS

The case library for RT IDSS should join in itself the cases concerning a particular subsystem of complex object, and also contain the information on each parameter which is used for the description of cases (parameter type and range).

Besides, the case library should include such adjustments, as:

– the significance of parameter;
– a threshold value of similarity;
– a value which limits quantity of considered cases.

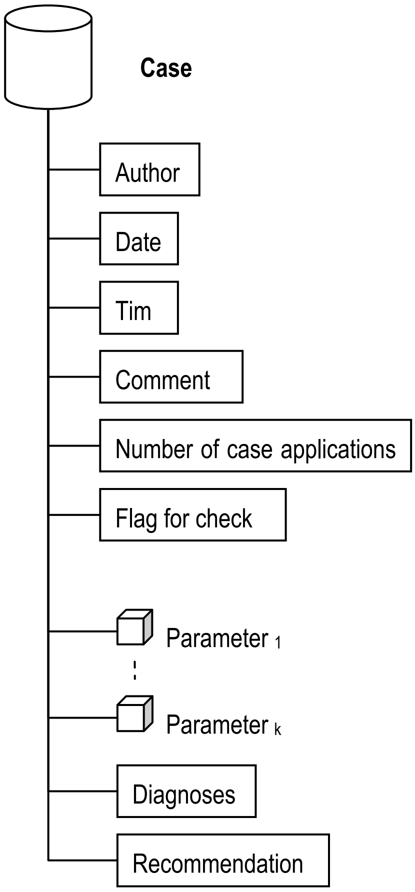


Fig. 3 Case structure

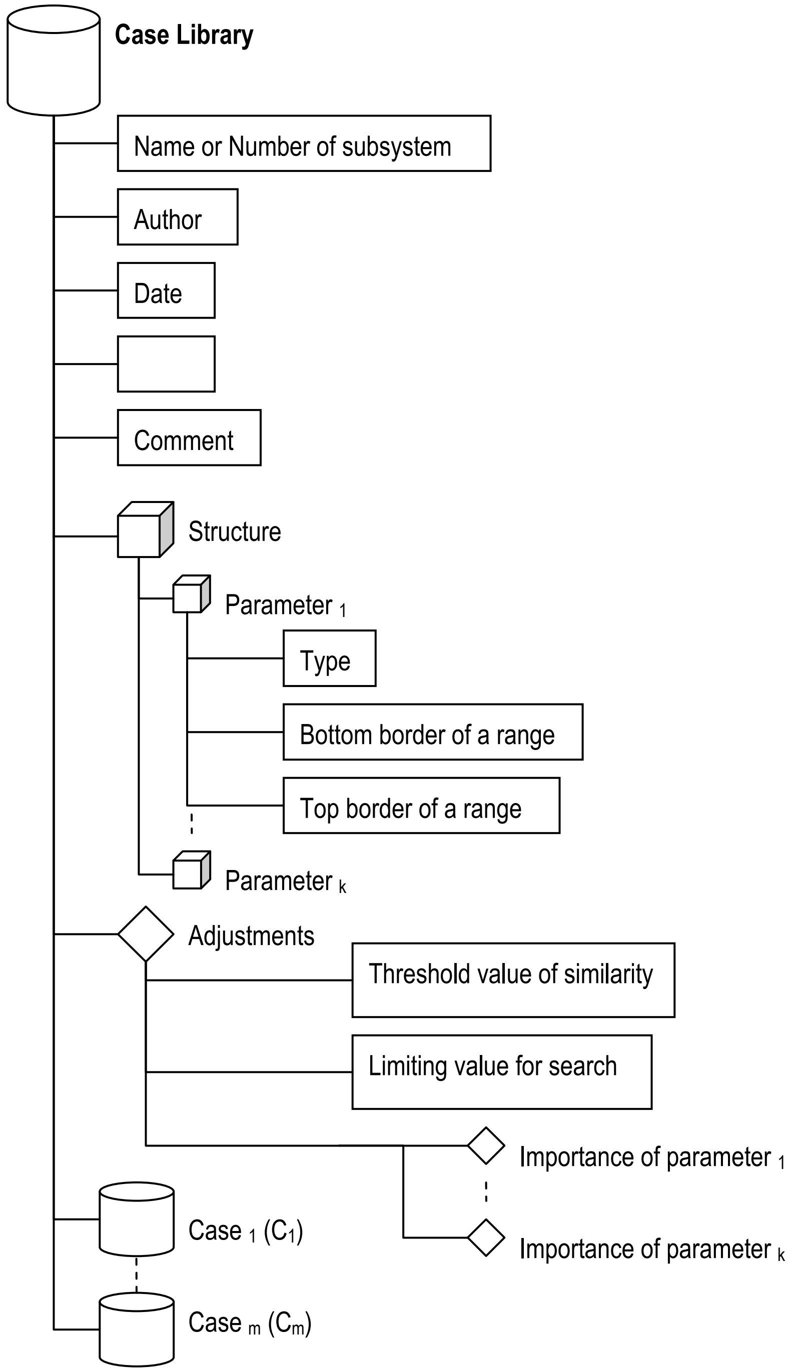


Fig. 4 The structure of case library for RT IDSS

It is necessary to emphasize, that the case library can be formed on the basis of:

- the experience, accumulated by the expert;
- analysis of the system archive;
- the analysis of emergencies;
- operative instructions;
- technological requirements.

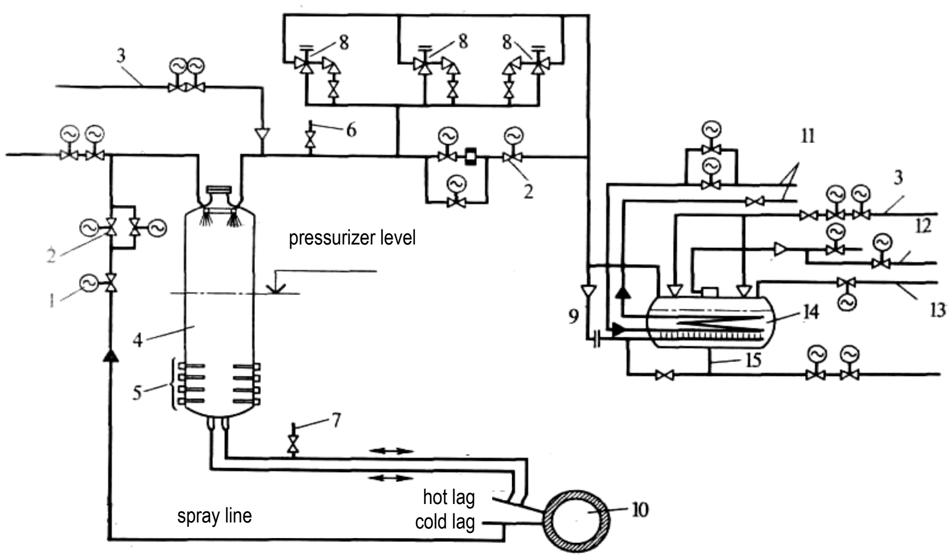
The case library can be included in the structure of the knowledge base of RT IDSS or act as a separate component of the system. Case structure is presented in fig. 3, and the structure of case library in fig. 4.

Application of case-based reasoning for diagnostics of complex object states

As a complex object, we shall understand an object which has a complex architecture with various interrelations, with a lot of controllable and operated parameters and small time for acceptance of operating influences. As a rule, such complex objects as the power unit are subdivided into technological subsystems and can function in various modes (in regular, emergency, etc.).

For the description of such complex object and its subsystems, the set of parameters is used. The state of object is characterized by a set of concrete values of parameters.

In the operative mode reading of parameters values from sensors for all object is made by the system of controllers with an interval in 4 seconds. For this time interval, it is necessary to give out to the DMP (operator) the diagnosis and the recommendation on the developed situation.



1 – isolation valve;
2 – control valve;
3 – nitrogen injection;
4 – pressurizer;
5 – electrical heaters;
6 – sampling of steam;
7 – sampling of water;
8 – safety relief valves;
9 – connector;
10 – reactor;
11 – cooling system;
12 – gas blowdown pipe;
13 – water sparger;
14 – relief tank;
15 – sampling system.

Fig. 5 The technological scheme of the steam pressurizer

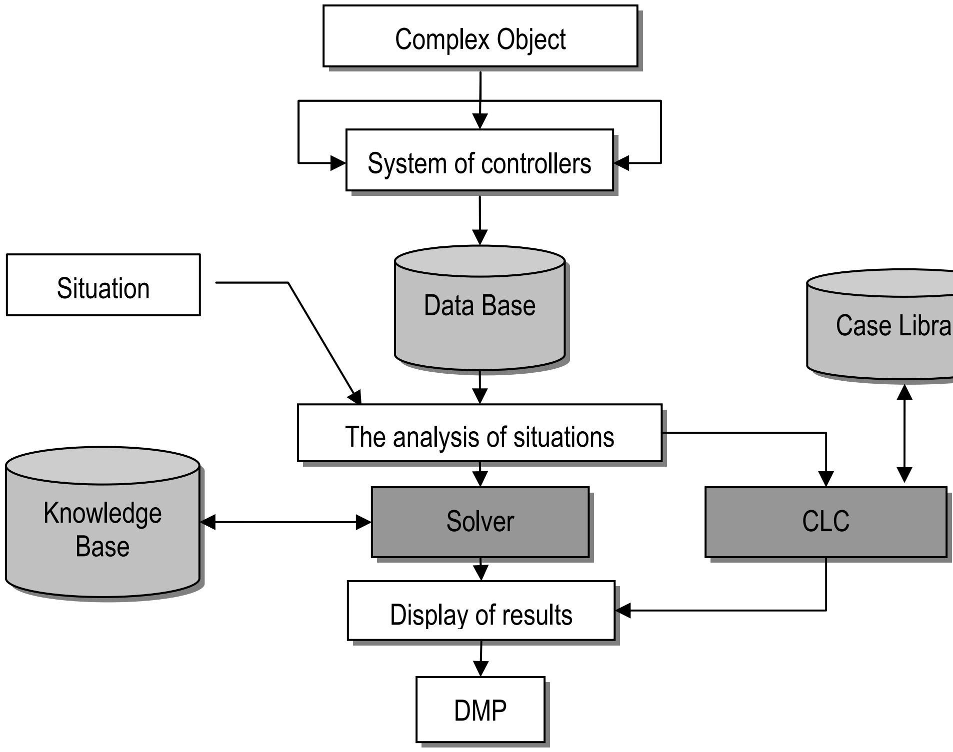


Fig. 6 The scheme of functioning for RT IDSS with use of CLC

Diagnosing and detection of operating influences is carried out on the basis of expert knowledge, technological requirements and operative instructions. The developed software (Case Libraries Constructor – CLC) can be applied to the decision of the specified problems.

Basic components of CLC are:

- module for storage and loadings case libraries and for data import;
- a subsystem of visualization for browsing the structure of case libraries;
- a subsystem of editing and adjustment of case libraries;
- a module of new cases check;
- a subsystem of case library testing and case-based reasoning.

CLC was implemented in Borland C++ Builder 6.0 for Windows NT/2000/XP.

This tool was applied in the prototype of a RT IDSS for monitoring and control of complex objects like power units on an example of a pressurizer in pressurized water reactor (PWR) of the atomic power station (fig. 5, 6).

Implementation of case libraries with use of CLC for systems of expert diagnosing is subdivided into the following main stages:

- Creation of case libraries for subsystems of complex object;
- Adjustment of the created case libraries;
- Addition of cases in case libraries;
- Check of the added cases;
- Testing of the filled case libraries with using case-based reasoning;
- Reservation of the created case libraries for their subsequent transfer to operative maintenance.

Conclusion

The method of case-based reasoning was considered from the aspect of its application in modern IDSS and RT IDSS, in particular, for a solution of problems of real-time diagnostics and forecasting.

The CBR-cycle is considered and its modification for application in RT IDSS is offered.

The k-nearest neighbors algorithm for definition of similarity degree of the current situation with cases from case library is described.

The structure of case library for RT IDSS is proposed.

The proposed method of case-based reasoning was implemented in Borland C++ Builder 6.0 for Windows NT/2000/XP. The main functional components of the implemented tool (Case Libraries Constructor – CLC) are specified.

The presented tool was applied in the prototype of a RT IDSS on the basis of non-classical logics for monitoring and control of complex objects like power units.

The possibility of application of analogous reasoning in case-based reasoning is underlined. We also note that the elements of case-based reasoning may be used successfully in analogy-based reasoning methods; i.e., these methods successfully complement each other and their integration in IDSS is very promising [8, 11].

Bibliography

1. Vagin V.N., Yeremeyev A.P. Modeling Human Reasoning in Intelligent Decision Support Systems // Proc. of the Ninth International Conference on Enterprise Information Systems. Volume AIDSS. Funchal, Madeira, Portugal, June 12-16, INSTICC, 2007, pp.277-282.
2. Vagin V.N., Eremeev A.P. Certain Basic Principles of Designing Real-Time Intelligent Decision Systems // Journal of Computer and Systems Sciences International, v. 40(6), 2001, pp. 953-961.
3. Kolodner J.L. Improving human decision making through case-based decision aiding // AI Magazine, 12(2), 1991, pp. 52–68.
4. Leake D.B. CBR in Context: The Present and Future // Case-Based Reasoning: Experiences, Lessons and Future Directions, AAAI Press / The MIT Press, 1996, pp. 3–31.
5. P.R. Varshavskii, A.P. Eremeev Analogy-Based Search for Solutions in Intelligent Systems of Decision Support. Integrated models and flexible calculations in artificial intelligence. Journal of Computer and Systems Sciences International, Vol. 44, No. 1, 2005, pp. 90–101.
6. Eremeev, P. Varshavsky Analogous Reasoning for Intelligent Decision Support Systems. Proceedings of the XI-th International Conference “Knowledge-Dialogue-Solution” – Varna, vol. 1, 2005, pp. 272-279.
7. A.P. Eremeev, P.R. Varshavsky Reasoning by structural analogy in intelligent decision support systems // Proceedings of the Seventh Joint Conference on Knowledge-Based Software Engineering JCKBSE’06. IOS Press, 2006, pp. 303-306.
8. Alexander Eremeev, Pavel Varshavsky Analogous Reasoning and Case-Based Reasoning for Intelligent Decision Support Systems // International Journal INFORMATION Theories & Applications (ITHEA) 2006, Vol.13 № 4, pp. 316-324.
9. Aamodt, E. Plaza “Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches”. AI Communications, No. 7, 1994.
10. Alexander Eremeev, Pavel Varshavsky Application of Case-based reasoning for Intelligent Decision Support Systems // Proceedings of the XIII-th International Conference “Knowledge-Dialogue-Solution” – Varna, vol. 1, 2007, pp. 163-169.
11. Eremeev A., Varshavsky P. Methods and Tools for Reasoning by Analogy in Intelligent Decision Support Systems // Proc. of the International Conference on Dependability of Computer Systems. Szklarska Poreba, Poland, 14-16 June, 2007, IEEE, pp.161-168.

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