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# Integration of case-based and rule-based reasoning through fuzzy inference in decision support systems

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**Abstract**

In the present paper we present an approach to facilitation of decision-making in the decision support systems (DSS). The approach is based on the transformation of knowledge from the implicit presentation in the form of cases stored in the case bases to the explicit presentation in the form of rules stored in the rule bases. The efficient method of decision-making on the basis of cases classification has been proposed. The method is based on the original algorithm of transformation of cases (precedents) sample to the set of linguistic rules allowing to make relevant decisions. Research of the method has shown good accuracy of the decisions classification on test data and dependence of the accuracy on the number of membership functions and the procedure of resolving conflicts between the rules.



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*Keywords:* case-based reasoning; fuzzy rule; classification; decision-making.

## 1. Introduction

Since the middle of XX century, great hopes were pinned on the research conducted in the field of artificial intelligence (AI)[1]. In the history of becoming AI as a scientific field, periods of optimism and expectations of rapid progress were regularly replaced by stagnation or even falling, when the results obtained were beginning to sound unconvincing and investment in the research work sharply reduced. However, the emergence in the 1970s knowledge based systems (KBS) for decision-making support were definitely associated with "success stories" in

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the scientific field when the AI methods began to be used in the real economy. By 1992 it was implemented about 2,000 such KBS systems2.

The core of designing the first expert systems for decision-making appeared in 1970-s was the model of knowledge representation based on rules (rule-based systems). When implementing KBS systems originally designed for the type of rules, developers face many challenges. The main one is the problem of knowledge extraction and formulating it in the form of a set of rules. Most often, the experts intuitively make decisions based on their vast experience, without hesitation, what rules they apply in this or that case. Breaking a specific behavior of an expert into independent building blocks such as rules in the rule-based system is very complicated (often insoluble) problem requiring highly skilled specialists - knowledge engineers. Therefore extraction of knowledge from experts is the kea problem of rule-based systems. Another problem is a disparity between the complexity of the real application domain for decision-making and very simple structure of IF-THEN rules.

To solve these problems, investigations were conducted to find the best methods[2], a variety of programs and environment has been developed, the development methodology has been improved[3,4,5]. To study complex application domains there were developed object-oriented modeling languages and ontology for modeling knowledge[6-9], methods and tools for decision support systems[10].

However, since 1980s an alternative reasoning paradigm has increasingly attracted more and more attention. Case-based reasoning (CBR) solves new problems by adapting previously successful solutions to similar problems. The work of Shank[11] in 1977 is widely known to be the origin of CBR. In this work is has been proposed to generalize knowledge about previous situations and store them in the form of scripts that can be used to make conclusions in the similar situations. Later Shank continued to explore the role that memory about previous situations (cases), represented as a knowledge container, plays both in the process of decision making and in the process of learning[12].

There are different ways of formulating the cases[13], from simple (linear) to complex hierarchical ones. A case could generally include a description of the problem and solution to the problem. If the cases are used to solve practical problems, the additional component may be the result of case application (positive or negative). It should be emphasized that already in the work[14] one can find references that natural domain concepts often cannot be classified according to a simple set of properties (features), and could be described by a more complex structure. This work was subsequently referred to as the philosophical basis of the case-based approach.

Case-based reasoning approach allowed to overcome a number of restrictions inherent to the systems based on rules[15]. First, CBR does not require explicit model of the knowledge domain, so the extraction of knowledge is transformed into a simple task of collecting stories (cases). Second, implementation of CBR-systems is reduced to the identification of essential features, describing the case, which is much easier task than building an explicit knowledge model of the application domain. Third, it is possible to use database technology for storing large volumes of cases. Forth, CBR-systems can be self-learning from the case base, thus, it is possible to obtain new cases.

At the same time there are some shortcomings of CBR. First, it should be noted that description of the cases do not usually take into account the deeper knowledge of the application domain. Second, the large case base results in reduced system performance. Moreover, it is difficult to determine good criteria for indexing and comparison of cases. Very often the search dictionaries and algorithms for determining similarity are needed to debug manually. It can neutralize the benefits of case approach.

Of course, many problems of rule-based and case-based approaches can be solved with use of contemporary object-oriented knowledge representation technologies. For example, in the work[16] it was proposed a hybrid model of knowledge representation that combines object-oriented representation and rule-based representation rules. At the same time it seems reasonable to combine the advantages of rule-based and case-based approaches in the integrated approach using hybrid model of knowledge representation.

It is worth to note that the first prototypes of such system integrating case base with the model in the form of rules were CABARET and MARS systems[17,18]. In present paper, a new approach is proposed in which it is possible the dynamic interaction of both models of knowledge representation. The essence of the approach is describe in section 2 where we also describe the method of transformation of case base to fuzzy rule base. Performance of the method is investigated in section 3.