VI. Classification of decision support systems

DSS can be classified into 9 different classes in accordance with the used information data, models and knowledge. In table 1 structure formulae for each class of DSS are represented [20].

Таблица 1

DSS classification

DSS structure formul	Information for decision making	Used data, models and knowledge
=objects+information + information collection tools	all which exists	all factual data about subject area
=alternatives+data + links	all which can be useful	actual data
=alternatives + criteria + criteria's values	all which is necessary (from that which exist)	relevant (selected) data
=data + models	all which can be formalized (modelled)	formalized data (actual models)
=models + rules criteria's estimations	all which must be modelled	relevant models
=rules of alternatives' estimation + alternatives' rating	any variants	results of decision variant modelling (actual knowledge)
=rules of alternatives' choice + set of acceptable alternatives	all the best (from that which exist)	relevant (generalized) knowledge
=problem situations + set of their decisions examples in the form of subject collections	all useful (about what formalized information exists)	formalized knowledge about existing experience (precedent base)
=inference system + best alternative	best (possible) variant	decision on the base of digital intellectualizing

This classification allows creating a more efficient enterprise business model. This is achieved mainly due to the rational management of automation systems for physical operations of production and related business processes, integrated into united information space in accordance with the key subsystems of the Industry 4.0 concept (Product Lifecycle Management, Big Data, SMART Factory, cyber-physical systems, Internet of Things, interoperability).

VII. Conclusion

In this research the experience of intelligent decision support and recommender systems construction is systematized. The concept of generalized object is formulated for DSS engineering. Principles of recommender systems are systematized, and include possible types of data filtering. Their advantages and disadvantages are analyzed. An example of recommender systems for musical tracks choice for the different sport trainings is presented. Classification of DSS and their structure formulae in accordance with the used information data, models and knowledge are suggested. The use of these results made possible to reduce the time for creating models by an order of magnitude. Also suggested principles of DSS and recommender systems design make the systems more transparent, and the results are more justified and explainable. Received experience can be used in development of next-generation intelligent DSS.

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ПРИНЦИПЫ И ОПЫТ ПРОЕКТИРОВАНИЯ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ И РЕКОМЕНДАТЕЛЬНЫХ СИСТЕМ Железко Б. А., Синявская О. А.

В статье рассмотрены основные принципы проектирования интеллектуальных систем поддержки принятия решений (СППР) и рекомендательных систем. Сформулированы определение и концепция обобщенного объекта. Проанализированы технологии проектирования и разработки рекомендательных систем. Предложена классификация СППР. Представлен опыт проектирования СППР и рекомендательных систем.

The Properties Generality Principle and Knowledge Discovery Classification

Viktor Krasnoproshin
Faculty of Applied Mathematics
and Computer Science
Belarussian State University
Minsk, Belarus
Email: krasnoproshin@bsu.by

Vadim Rodchenko and Anna Karkanitsa
Faculty of Mathematics and Informatics
Yanka Kupala State University
of Grodno
Grodno, Belarus
Email: rovar@grsu.by, a.karkanica@grsu.by

Keywords—intelligent systems, pattern recognition, learning from examples, data mining **Abstract—The paper examines the actual problem of automatic detection of hidden interpretable patterns in intelligent systems. The conceptual basis of the process of learning from examples is determined by the methods of class description and separation. Three basic principles are known: enumeration of class members, generality of properties and clustering. We propose an original method for implementing the principle of generality of properties based on the search for combinations of features that provide class distinction. The effectiveness of the approach is confirmed by the results of numerical experiment.**

***Keywords*—intelligent systems, pattern recognition, learning from examples, data mining**

I. Introduction

The development and large-scale implementation of information technologies has led to the accumulation of huge amounts of data, which today are organized into databases and data warehouses [1], [2]. Currently, the development of new methods aimed at improving the efficiency of representation and automatic knowledge extraction based on the analysis of large amounts of data is an urgent problem in computer science [3], [4].

The experience of using the structured query language (SQL) has shown its very limited capabilities in terms of discovering hidden patterns existing within the data. OLAP technology (interactive analytical data processing) is focused on the preparation of aggregated information on the basis of large data sets structured according to the multidimensional principle. At best, the technology provides for the extraction of knowledge from the data, which should be attributed to the "shallow"level of occurrence. The most interesting in practical terms are the hidden patterns, the detection of which is the focus of Data Mining [5]–[7].

In computer science, the problem of pattern recognition is one of the fundamental problems [8]–[10]. Its successful solution largely determines the progress in the field of artificial intelligence. Pattern recognition is the attribution of initial data to a certain class based on the selection of essential distinguishing features that characterize this data [11]–[14].

If a class is characterized by some common properties inherent in all its members, the construction of a recognition system can be based on the principle of generality of properties. The basic assumption in this case is that patterns of the same class have common properties reflecting their similarity [15], [16].

The paper proposes an original method of implementing the principle of generality of properties. It is assumed that as a result of analyzing the training data set (TS) it is possible to identify such a combination of features that ensure the distinction of classes. That eventually make the procedure of building a classification algorithm quite trivial. The effectiveness of the method is confirmed by the results of numerical experiment.

II. On Pattern Recognition Principles and Classification Problem

The basis of the idea of building automatic recognition systems are the methods of describing and separating classes (Fig. 1) [17]

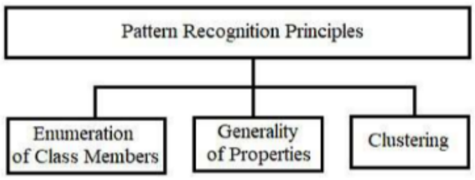

Figure 1. Principles of Pattern Recognition.

When a class is defined by an enumeration of its constituent objects, the construction of a pattern recognition system can be based on the principle of belonging to this enumeration. A set of objects of the class is memorized by the recognition system, and when a new object is presented to the system, it assigns it to the class to which the object located in the system's memory that matches the new one belonged (Fig. 2)

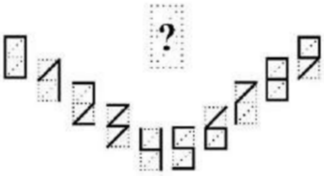

Figure 2. Enumeration of Class Members.

If all objects of one class have a number of common properties or features that are absent or have other values in all representatives of other classes, then the construction of the recognition system can be implemented on the basis of the principle of generality of properties (Fig. 3).

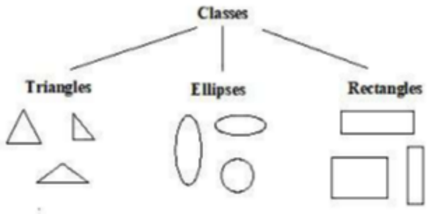

Figure 3. Generality of Properties.

When the objects of a class are vectors in the feature space, the class can be considered as a cluster. If clusters of different classes are separated far enough from each other, then the construction of the recognition system can be carried out using the clustering principle ??(Fig. 4).

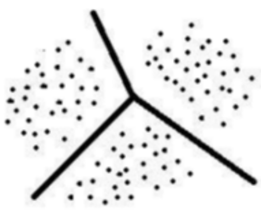

Figure 4. Clustering

Traditionally, when building automatic pattern recognition systems, three main problems are solved. The first one is devoted to the issues of representation of the initial data obtained as a result of measurements of the recognized object. The second task is related to the extraction of essential features and properties from the initial data. The third one consists in finding optimal decision rules for classification [18], [19].

In [19], the author, discussing the problem of the simplicity of the learning process in pattern recognition, notes the existence of two different approaches to its implementation. In author's opinion, in the vast majority of studies (the first group), the learning process is aimed at constructing solving rules that ensure the extremum of a pre-selected criterion. In the second group, the focus is on understanding the principles of forming the description of recognition objects, within which the recognition process becomes extremely simple. Learning in this case is seen as a process of constructing a space that is universal, if not for all, then for a wide class of tasks. Unfortunately, in the author's opinion, this group of studies is very few and such an approach to solving the recognition problem is still poorly studied.

Today, pattern recognition is dominated by an approach in which training is reduced to solving an optimization problem. The training process begins with the selection of an initial model (a parametric family of algorithms), and then it is assumed that the "training + testing" scenario is repeatedly executed. In fact, training is an iterative process in which positive and negative reinforcements are used to form the desired patterns of classifier behavior.

In this case, it should be pointed out that there are at least two serious problems. First, model selection is a non-trivial task performed by a data science specialist, and therefore the training process can be implemented only in an automated mode. Second, the only result of training is a classification algorithm, which is an uninterpretable "black box".

It is proposed to consider an alternative approach, when the construction of the classification algorithm is performed not within the framework of the optimization problem, but on the basis of the analysis of the properties of the considered classes. As a result of such analysis, the distinguishing properties are determined by the mutual placement of the areas of class definition — patterns.

Before proceeding to the presentation of the alternative approach, let us consider the classical version of the mathematical formulation of the recognition problem.

In the paper by Y. I. Zhuravlev [20], the following formulation of the recognition problem (classification or Z problem) is given:

Let there be a set of admissible objects M. The set is covered by a finite number of subsets $\boldsymbol{K}_1, ..., K_l : M = \cup_{i=1}^{l}$

and the description of the admissible object I(S).The main problem (problem Z) is to compute the values of predicates $\boldsymbol{P}_j(S)SK_j, j = 1, 2, ..., l, from the information I_o(K_1, ..., K_l)]$
and the description of the admissible object I(S).