Uniwersytet
Ekonomiczny
w Katowicach

Studia Ekonomiczne. Zeszyty Naukowe
Uniwersytetu Ekonomicznego w Katowicach
ISSN 2083-8611 Nr 243 · 2015

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ONTOLOGY OF DATA MINING IN THE INTELLIGENT DASHBOARD FOR MANAGERS

Summary: This paper presents the approach to a description of the knowledge of data mining as a module ontology DM in the Intelligent Dashboard for Managers on the example of the implemented system called InKoM. The ground knowledge is focused on selected concepts and associated data mining algorithms . As a result, the system provides the necessary functionalities for managers of small and medium-sized enterprises. The ontology of data mining provides, o especially for inexperienced managers, substantial support in decision making processes and simultaneously improves the quality and effectiveness of knowledge discovery. In this paper, the motivation for the project, the concepts, the process of creating ontology, and particularly the stage of the conceptualization phase are described. The application of the considered InKoM system with implemented ontology of data mining is discussed to demonstrate its permanent usefulness for managers.

Keywords: ontology of data mining, dashboard for managers, BI systems.

Introduction

The ontology of knowledge discovery is a new discipline which was designed for presenting domain knowledge in data mining systems. The first systems with an implemented prototype version of ontology were CITRUS [28], CAMLET [27], and Mining Mart [5, 25]. A more advanced solution for automatization of the process of data mining was the ontology based on the hierarchy of data mining operators in the IDA [21], implemented in the e-lico project [13].

Other examples of non-standard approaches to the ontology of data mining are NeOn [26], NExT [2] and GridMiner Assistant [3].

There is no leading technology in the field of ontology data mining because work on finding a golden mean is still ongoing. An extensive discussion [8, 9, 10, 15] on the construction ontology, creation of a knowledge base, and implementation can depend on its practical application in data mining systems. The ontology presented in this paper relates to the area of system management.

Many data mining systems have been created for professionals. Currently, in order to meet the needs of a manager, the programs are designed not only in regard to a friendly environment. Such tools as data visualization, automatic navigators, and dictionaries, are not sufficient to correctly perform the process of knowledge extraction. In addition to the graphical interface, they focus more often on assisting users conceptually in the process of knowledge discovery. To make this process easier for managers and more efficient, in many systems, the ontology is implemented. An approach often chosen is where the concepts are already implemented in information systems that have proved their usefulness, credibility, and reliability. That was the main reason to integrate the ontology with the existing Business Intelligence system, developed by TETA BI Center [20]. The advantage was to link the data warehouse structure directly with the concepts, financial ontologies, and data used by data mining algorithms.

The Intelligent Dashboard for Managers [22], here referred to as InKoM, presents an innovative approach to defining knowledge in the field of finance and data mining[1]. It is a complex Business Intelligence solution for managers of Small and Medium-sized Enterprises (SMEs). InKoM is a response to the needs of executives that allows advanced economic and financial analyses, by providing related substantive knowledge in the form of ontology. InKoM includes all the key features that are essential for the management of SMEs. It includes the analysis of economic and financial indicators and implementation of data mining methods. The ontology of data mining constitutes the explicit and formal description of knowledge in data mining. Its main task is to assist a manager at every stage of the process of data mining along with defining the relevant concepts and relationships to knowledge discovery processes.

The purpose of this paper is to present the structure and usability of data mining ontology in InKoM. The first section provides an overview of the results of research on evaluation of analysis and data mining systems carried out by the

[1] The Intelligent Dashboard for Managers is the result of a project carried out by the Wroclaw University of Economics, Poland. The project was co-financed by the National Research and Development Centre (NRDC) under the INNOTECH program.

USDA Forest Service (USFS) [14]. The work shows the important role of interface and domain knowledge in supporting it. The second section presents the ontologies implemented in the InKoM system. The next section concerns the procedure of creating the ontologies mentioned above, with particular focus on the actual conceptualization of the knowledge of data extraction. The fourth section explains the concept of the data mining model in the form of topic maps. The next section concerns the method of ontology encoding using the Ontopia editor [16]. Finally, practical usage of the ontology of data mining is shown.

1. The role of ontology in data mining systems

The growing demand for advanced data analysis with a focus on the economic and business areas, was a reason for developing data mining platforms. The choice of platform is usually a subjective process that depends entirely on the users and their individual preferences. The knowledge contained in the ontology allows the selection of Business Intelligent systems regardless of user skills. However, when a defined ontology does not exist, there is a lot of room for determinant selection. To make this choice more objective, Table 1 proposes the essential criteria. The study was carried out by the USDA Forest Service (USFS) and concerned comparisons of the most popular data mining systems. Selected packages include open source R [18], Weka [12], Orange [11], and commercial SAS Enterprise Miner [19]. Orange and SAS are based on a graphical interface that visualizes tasks and decision-making processes. Weka has a modular structure that allows for quick settings and operations on the data file, while R contains a script-based data mining environment.

General evaluation criteria are universal and concern usability, critical mass, uniqueness, performance, and other elements (cost, reviews). Each group is a set of specific determinants, but it is worth noting that some groups depend somewhat on each other, for instance: the difficulty of service and the uniqueness of interface. A program which does not allow the execution of tasks in a transparent manner creates problems. Technical support in the context of information constitutes a substantive knowledge of the operation and the functionality of the program, e.g. in the form of manuals or dictionaries. It should also be noticed that a number of users may indirectly affect the positive assessment of the system; in particular the functionalities that are compatible with the workstyle of managers.

Table 1. Evaluation of data mining platforms by an expert assessment of the USDA Forest Service (USFS), adapted from [6]

		R	**Weka**	**Orange**	**SAS Enterprise Miner**
USABILITY	Interface Difficulty	●			
	Variety of Models/ Options	△	▲	□	△
	Language/ Programmability Difficulty				
	Integration with other Software				
CRITICAL MASS	Number of Users				
	Tech Support				
	Longevity				
UNIQUENESS	Algorithms				
	Interface Abilities				
PERFORMANCE	Speed				
	Accuracy				
	Stability				
OTHER	Cost				
	Peer-reviewed Publications				
OVERALL RANKING					▲

Legend:

– High Favorable Rank

– One Below High Rank

– Middle Rank

– One Above Low Rank

– Low Favorable Rank

On this basis, the main contribution of this paper is to present how ontology can very easily support the inexperienced manager in advanced analyzes. Further consideration will show that the knowledge contained in ontologies is carefully selected and useful.

2. Ontology in the InKoM system

The main objective of the Intelligent Dashboard for Managers is to provide substantial support for SME managers to understand financial data, interpret them, and use them in decision making processes. The Intelligent Dashboard for Managers allows semi-automatic implementation of complex exploration tasks, using domain and data mining ontologies (see Fig. 1). Both are independent components of InKoM, where the extraction of a new knowledge can be based either on explicitly defined relationships in financial ontologies, or results of data mining processes [4, 23].

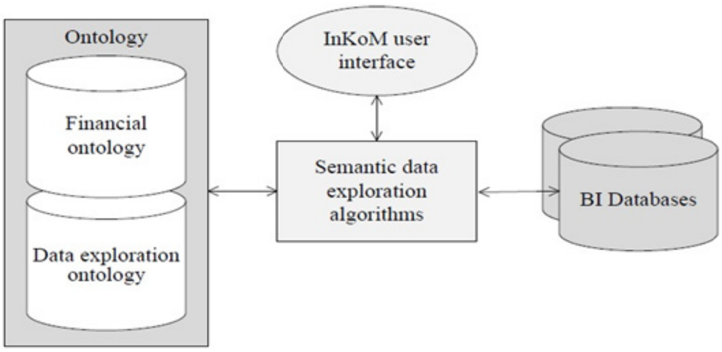

Fig. 1. Scheme of the semantic architecture of data mining, adapted from [23]

Domain ontology deals with economic and financial knowledge which is to contribute to a better interpretation of the terms and the associated indicators. Six ontologies for selected areas of economic analysis were built, which include: estimating Cash Flow at Risk, Comprehensive Risk Measurement, Early Warning Models, Credit Scoring, the Financial Market, and General Financial Knowledge [4]. The division of the ontology was the result of theoretical work by the project team and the experience of BI practitioners.

The ontology of data mining in InKoM contains a description of mining algorithms that are also available on multiple data analysis platforms such as WEKA, Orange, Statistica, R, MSDN [29]. Taking into consideration the requirements of managers, the algorithms were limited to: algorithms for data pre-processing, classification, clustering, trend, and forecasting methods. The ontology of algorithms explains the objectives, constraints, and interpretation of parameters and I/O data in the process of building a decision-making model. It supports managers by providing typical scenarios (workflows) for a data mining process.

An interface based on ontology actively supports managers while working in the system and helps them to achieve more reliable and useful results in less time.

3. The process of creating ontologies in the InKoM system

The idea of creating ontologies for InKoM came from the analysis of the most interesting design approaches, including: METHONTOLOGY (based on IEEE 1074-1995), UPON method (Unified Process for ONtology building), Noya and McGuinness, SENSUS, TOVE (Toronto Virtual Enterprise project), On-To-Knowledge, and the methodology of Ushold and King [4, 24]. As a result, the process of ontology was divided into five basic steps:

1) Determining the purpose, scope and limitations of the created ontology.
2) Conceptualization of the ontology.
3) Verification of the ontology by experts.
4) Encoding of the ontology.
5) Validation and verification of the created ontology.

The conceptualization phase is the most important and also a key step in the construction of ontologies. It was divided according to different algorithms and methods, such as the initial preparation of data and generating the rules. Its correctness, in terms of content, directly affects its usability in the system [1]. At this stage, three different approaches are possible, i.e., bottom-up, top-down, and middle-out. An indirect method for building ontologies was chosen, because it allows the user to maintain control over its level of detail, while reducing potential inaccuracies. The conceptualization of knowledge includes activities such as: identification of concepts, defining classes and hierarchical structures (*Superclass – Subclass*), modeling relationships, establishing instances, axioms and inference rules. The formalization of knowledge takes place in accordance with the format outlined by the standard of a topic map. The next step is the verification of the ontology by independent experts in data mining. The character of encoding the ontology determines its further use in the system. In contrast, the validation and evaluation of the usability of each ontology in the system is achieved through case studies from the managerial perspective.

The ontology of a data mining model on the conceptual level is described in two aspects. On the one hand, the ontology specification was presented in the form of diagrams, representing a static representation. Schemes of ontologies represent identified types of concepts and relationships between them[2]. By contrast, a dynamic aspect of ontology describes scenarios for data mining processes. Fig. 2 shows a general diagram of data mining ontology. The rectangles represent the types of concepts. The diagrams do not present instances of concept types. For example, for the type of the concept algorithms of data mining, the diagram contains two fields: locating the object in the system, and a description of the algorithm. The location of the object in the system stores a reference to the object in the ontology. The second field describes the algorithm.

Fig. 2 presents the general fragment of a complex scheme of the ontology of data mining that includes all the ontologies of data mining algorithms. Beside types of concepts, relationships are essential components of the diagram. Relationships define the relations between concepts. In all schemes of data mining ontology there are two basic types of relationships: *class_of*, *is_aggregate*. The *class_of* relationship indicates the generalization and inheritance, and describes the structure of classes and subclasses (*Superclass – Subclass*). In turn, *is_aggregate* means the relationship is a concept that is part of or subordinate to another concept. For example, Input data and Output data are the type of concept inherited from the Data, while the same I/O data are included in the type Algorithms of data mining. Information is the essence and the focal point of the scheme of data mining ontology. It consists of the Sources (all links concerning objects that store data files such as Excel files, database), Attributes, Financial ontology (domain) and Data warehouse.

The practical aim of the ontology is to provide useful knowledge to managers in the data mining process. Firstly, data mining algorithms are chosen. In the system the following algorithms were implemented: decision tree algorithms, association rules, neural networks (MLP), cluster analysis (k-Means), and trends. The InKoM system supports managers in the selection and parameterization of these algorithms, as well as in the data pre-processing, results assessment, and updating of domain knowledge. Creating the ontology of data mining is complex, because beside the description of complex algorithms/methods, they must cooperate with the domain ontology. Moreover, the active assistance provided by the ontology should contain descriptions of the algorithms and the interaction of specific steps in the process of exploration. Summing up, the key function of data mining ontology is navigating the knowledge extraction procedure in such a way as to ensure its proper use and to avoid mistakes and any negligence.

[2] A type of concept is understood as a class, which is an abstract term.

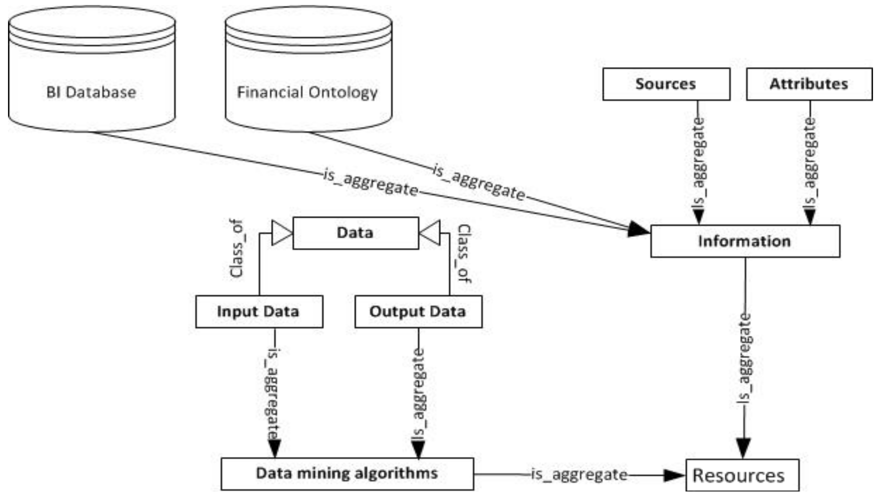

Fig. 2. General scheme of data mining ontology

4. Encoding ontology in the Ontopia editor

Encoding is the fourth stage of building ontology, and consists in its formalization in the specific language. Ontopia is an open source tool for creating applications based on a standard topic map [17]. It allows the user, among other tasks, to edit instance data, store databases, design individual ontologies, and fill topic maps manually or automatically, and provides a fully ergonomic query language [16]. This is very important, because the visual context of the study in the InKoM system is based exactly on this standard (TM – ISO / IEC 13250:2003). Topic maps allow us to represent complex structures of knowledge bases and provide a useful model of their representation. By focusing on the semantics of the data, using multiple context indexing, we are able to find the information easily and quickly.

The ontology of data mining was encoded in Ontopia based on previously established patterns. The process of defining a simple relationship is shown in Fig. 3. This is a part of the general scheme of data mining ontology. Specification of ontologies using Ontopia begins with the declaration of types of concepts. Then the concept needs to be edited by entering appropriate settings. Although the wizard does not require more information, it is recommended that we add the description of a field type. The first declared type of the concept is Data that is superior to I/O data. *Superclass* and *Subclass* fields stay empty, because they are used to select types of concepts which are by turns *Superclass* or *Subclass* of the created concept. Other types of concepts are introduced in the same way, with the exception of the settings of the fields *Superclass* and *Subclass.* Both the Input and Output data are descendants of the concept Data.

The concepts of data mining ontology encoded in Ontopia form a hierarchical structure of classes and subclasses. Each of the concepts is a standalone object in the topic map. A manager using a topic map is able to *navigate* between selected algorithms. Taking into account the fact of the connection between types of topics with objects of the information system, the system allows the manager to preview the processed data and, consequently, he or she can learn more about individual components of the data mining procedures. The manager can easily analyze the data mining processes carried out, compare their results, and focus only on those which are crucial (processes or stages of the process).

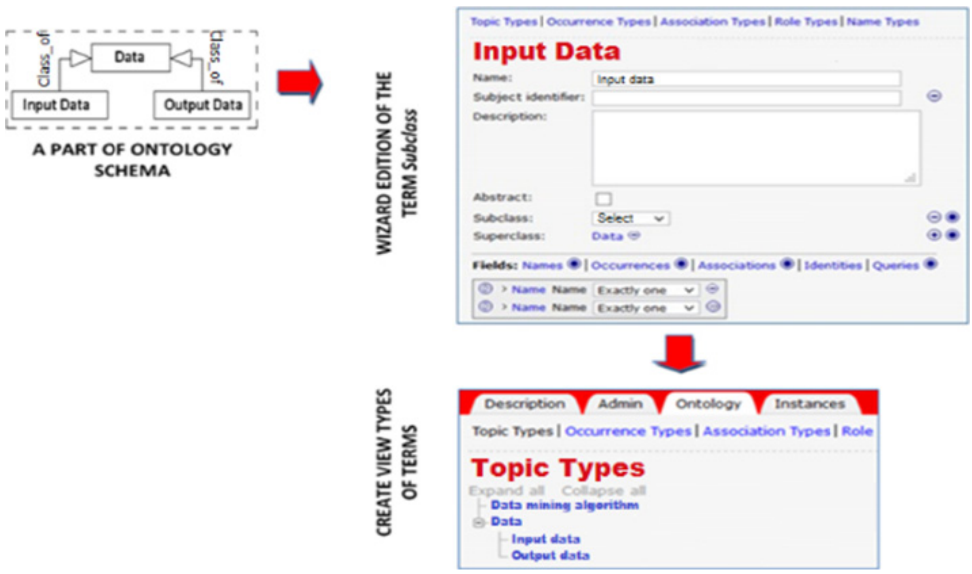

Fig. 3. Creating concepts and relationships in the editor Ontopia

The final work was to transform the thematic maps into XTM files. The aim of the XTM (XML Topic Maps) is to express thematic maps in ISO 13250 standard, using the universal language of XML [23]. XTM format is an extension of XML syntax and specifies the scheme of topic maps [17]. The last stage of encoding ontology concerns mainly the tasks on the technical side of the project. Verification of maps was finally made by experts who did not participate in their design. This step involved checking the maps which present ontological knowledge regarding the content and its relationships. The interpreter of XTM language implements the ontology accepted by the experts, together with visualization of maps. The ontology of data mining should be integrated with the financial ontology, but also with the BI system. This task is envisaged in the next version of the InKoM.

5. Scenario of using ontologies of data mining in the InKoM system

The practical use of the InKoM system with the implemented ontology of data mining was performed using specific usage scenarios.

This section presents a case study of customer loyalty. It is assumed that the company manufactures radiators and operates on a national scale. Although the company has been in existence only one and a half years, it has had time to build an impressive customer base, but recently there has been a decline in orders caused by losing several contractors. After the evaluation, it turned out that most of the customers received a better offer from rival companies. In this situation, the company had quickly to convert and implement a new strategy for customer service. The first step was to create stronger relationships by providing attractive discounts on the purchase of heaters, as well as trade credits (with a payment date of up to six months). On the basis of their decisions in sales reports, the marketing managers had to identify the first target group of customers to whom new offers were to be addressed. These were the wholesalers with the highest percentage of orders and operating in the cities with the highest number of orders. It was expected that this approach would ensure the retention of customers who generated high revenues while reducing costs, which is connected with fewer perks. In addition, the company wanted to avoid additional burdens associated with delegating sales representatives.

The manager having the Intelligent Dashboard for Managers at his disposal can easily get the desired information and predict future economic events. The system, powered by reported data in the form of OLAP cube views, makes available all the parameters, measures, and dimensions of the object in a SALE file. When the wizard starts adding the data mining model, the manager receives a list of steps to create a decision-making model. In addition to the on-going description of each step in the wizard, which provides an explanation and introduces the manager to the operation, there is all the while ontology and assistance available.

Given the general nature of how the concept and the use of data mining ontology are presented, only the elementary stages of the process of discovering knowledge will be shown in the InKoM system. The detailed procedure for the manager to solve this problem has been described in the thesis of I. Heppner [7]. The model of loyal customers is a typical example of a method of classification. The manager, not knowing what algorithm to choose, familiarizes himself with the description of the inductive decision tree method and neural networks. The ontology, by contrast, presents both algorithms in the context of the whole process of data mining, taking into account abstract connections of concepts associated with them. The transition from the data mining software layer to the ontology of data mining layer allows the manager to navigate the whole procedure of extracting knowledge automatically. The network of relationships between the choice of algorithm and the BI base and its components is shown in Fig. 4.

Just as in the previous steps, the choice of algorithm in the wizard ensures the automatic transfer to this type of concept on the map of ontology. The manager moving to a particular part of the graph can see all the possible links between the various types of concepts. The color of a relationship determines its type: red (solid line) – *class_of*, orange (dashed line) – *is_aggregate*. The manager can disable one or all connections, which then enables better interpretation of the graph. The premises for using the algorithm lead the manager to select the algorithm of Inductive decision trees, which is a class derived from *Data mining algorithms*.

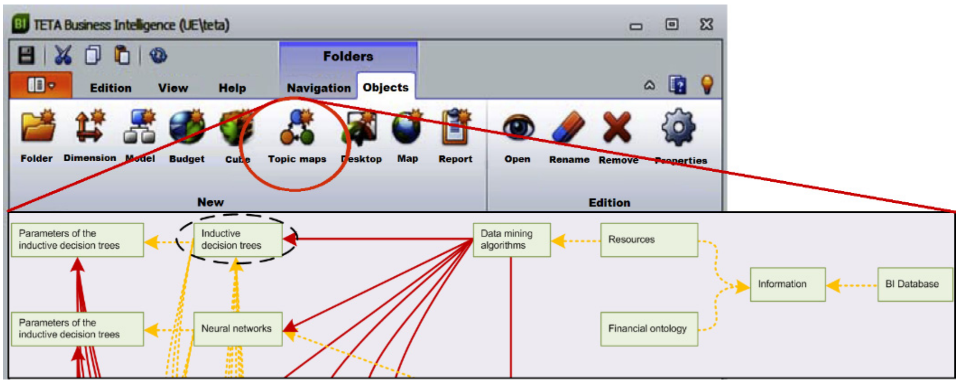

Fig. 4. A part of the ontology for the classification in the context of algorithm selection

For an inexperienced manager, establishing the parameters of an algorithm can be a big obstacle in building a proper model. In Fig. 5, the ontology of data mining defines a set of parameters determined in the context of different algorithms, here inductive decision trees. The manager can learn more about the various indicators by typing the name in the text box search in the view of ontology. As in the previous steps, each parameter is briefly explained.

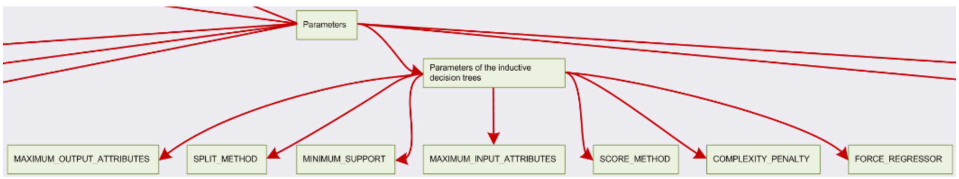

Fig. 5. A part of the ontology with basic parameters of decision trees

The basic parameters of a decision tree specify its complexity (complexity penalty) and the maximum number of input attributes (maximum input attributes). Showing the user the range of values for each parameter in the wizard, as well as default values, greatly simplifies his decisions and eliminates the trivial mistakes in this regard. The manager can select a default value, which for the complexity of the tree is 0.50 and for the maximum number of attributes is 255.

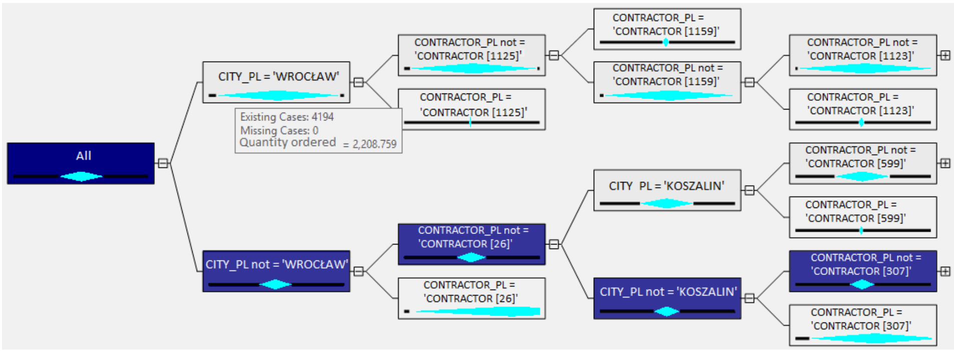

Fig. 6. A fragment of the decision tree model

The result of data mining carried out by the manager is a model of a decision tree. It is a graphic formulation of decision rules which allows the user to solve the problem of classification. Fig. 6 shows a part of an extended tree where a dark blue color indicates the preferred path of decision along with its consequences. The manager, working from a tree visualization, can, in a simple and intuitive way, identify and interpret the way of selecting "the best" customers in the cities with the highest level of sales.

In our case study, the marketing manager selects in the first place the city in which the number of orders exceeded one million. One of them is Wroclaw, where the level of orders is more than twice as high as expected. In order to achieve a commensurate group of clients, the share of their orders in the total number of orders in the given location must oscillate in the minimum limit of 32%. The contractor with ID No. 1125 qualifies for the group of customers we are searching for, with the number of orders of over 752,000. And the customer 1159 with the result of around 502,000 is not be taken into account.

The module of the data mining ontology actively supports the manager in using InKoM. Despite the completed work implementation, which has not shown the whole functionality of the system, the ontology of data mining is still at the pilot level, where a preliminary version is passing beta test now.

Summary and further work

The prototype of the Intelligent Dashboard for Managers includes the selected areas of data mining knowledge that can be useful for managerial activities. The idea of ontology was inspired by known data mining methodologies and best practices of knowledge discovery. Having designed the system, we were focused on easy-to-use functions and active piloting of the knowledge extraction process, which make it possible for even an inexperienced manager to be able to perform complex data analysis.

In work for the future, we have plans for a decision rule generator to transform the new knowledge into the system ontology. In this way, we expect to be able to dispose a functionality to update the domain knowledge of the system. In addition, we expect to enrich the interface through integrating a roadmap of the data mining process with a collection of useful decision-making models. Decisions on the commercialization of the Intelligent Dashboard for Managers will be taken soon; this depends on the final assessment by practitioners, as well as the results of the on-going monitoring of system usability.

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ONTOLOGIA EKSPLORACJI DANYCH W INTELIGENTNYM KOKPICIE DLA MENEDŻERÓW

Streszczenie: W artykule przedstawiono niekonwencjonalne podejście odwzorowania wiedzy z zakresu eksploracji danych (*Data Mining*) jako modułu ontologii DM w Inteligentnym Kokpicie dla Menedżerów, dalej zwanego system InKoM. Jest to kompleksowe rozwiązanie technologii systemów klasy BI zarówno dla średnich, jak i mikroprzedsiębiorstw. Optymalna selekcja pojęć i algorytmów eksploracji danych w zaimplementowanej ontologii systemu pozwala na poprawną identyfikację wniosków oraz zwiększa możliwości percepcyjne menedżera, zwłaszcza niedoświadczonego. InKoM jest odpowiedzią na zapotrzebowanie kadry kierowniczej na program ekspercki, który umożliwia niezależność i swobodę działania w zakresie zaawansowanych analiz, wspierając jednocześnie procesy decyzyjne oraz poprawiając jakość i skuteczność odkrywania wiedzy. W niniejszej pracy zaprezentowano motywację projektu, koncepcje oraz proces tworzenia ontologii, ze szczególnym uwzględnieniem fazy konceptualizacji. Zastosowanie systemu InKoM dla studium przypadku ma na celu wykazanie efektywności i przydatności modelu decyzyjnego dla menedżera.

Słowa kluczowe: ontologia eksploracji danych, kokpit menedżerski, systemy BI.